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The Geology of Gold Prospects in the North Caribou Lake Greenstone Belt, District of Kenora, Northwestern Ontario

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The Geology of Gold Prospects in the North Caribou Lake Greenstone Belt, District of Kenora, Northwestern Ontario

by

D.W. Piroshco, F.W. Breaks, and I.A. Osmani

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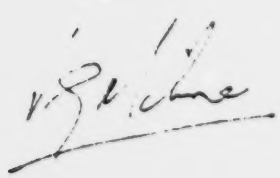
FOREWORD

The North Caribou Lake Greenstone Belt has, since the early 1980's, been the focus of extensive exploration for gold. In 1984, the Ontario Geological Survey initiated a multi-disciplinary study of the belt, including Precambrian bedrock mapping, mineral deposits studies, and studies of the surficial geology, to provide explorationists with a comprehensive, current geological database. Preliminary maps from this work have been released, and a final report encompassing all aspects of the project is in preparation.

This report contains descriptions of the known gold occurrences in the belt, and of a previously unknown occurrence of platinum group elements, as well as a brief summary of the metallogenesis of the belt. It has been prepared and released in advance of the final report in order to provide this information as quickly as possible to exploration geologists and prospectors interested in the North Caribou Lake Greenstone Belt.



V.G. Milne
Director, Ontario Geological Survey

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ABSTRACT

Gold prospects in the North Caribou Lake Greenstone Belt, located 150 to 200 km north of Pickle Lake, are hosted within both greenschist (Agutua Arm and Neawagank Lake areas) and amphibolite (Opapimiskan Lake and North Rim areas) grade rocks. The most significant occurrences discovered to date are within amphibolite grade rocks in the Opapimiskan Lake area (*i.e.* the West Anticline and Snoppy Lake zones).

The most consistent geological feature common to the occurrences throughout the belt is their close spatial relationship with lithologically and structurally complex areas. Gold is hosted within iron formation and iron-rich schist near the crest of complex (10's of metres to kilometre scale) fold structures in the Opapimiskan Lake area, and within similar lithologies along a shear zone in the North Rim area. Gold is hosted within Fe-Mg carbonate-rich and mafic volcanic rocks along one to 100 metre wide shear zones in the Agutua Arm area and within metre-scale shear zones in gabbroic rock in the Neawagank Lake area.

Other geological features of the occurrences can be explained in terms of metamorphic grade. Gold within amphibolite grade rocks occurs with sulphides (pyrrhotite, arsenopyrite) sparsely disseminated in the wall rock. Quartz veins are a minor component of the mineralization, and wall rock alteration is subtle. For example, wall rock alteration within the West Anticline Zone is characterized by the gruneritization of magnetite and an increase in garnet content. However, both of these

features tend to be widespread on a regional scale, reflecting the bulk composition of the iron-rich rock, and, therefore, are difficult to use as exploration guides. Gold within shear zones in greenschist grade rocks occurs with massive to disseminated sulphides (arsenopyrite, chalcopyrite, pyrite) locally distributed in lenticular quartz veins. Negligible gold occurs in the wallrock, which is locally altered to quartz + carbonate or quartz + sulphide (pyrite, arsenopyrite) adjacent to the quartz veins.

All of the geological features provide criteria for further gold exploration in the belt. The best criteria on a regional scale are the recognition of complexly folded iron formation and the recognition of shear zones. On a detailed scale, the best criterion is the recognition of sulphides. Quartz veins, and alteration related to the mineralization, may be absent or difficult to recognize.

THE GEOLOGY OF GOLD PROSPECTS IN THE NORTH CARIBOU LAKE GREENSTONE BELT, DISTRICT OF KENORA, NORTHWESTERN ONTARIO

by

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Manuscript approved for publication by V.G. Milne, Director, Ontario Geological Survey, October, 24, 1988.

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INTRODUCTION

In 1984, the Ontario Geological Survey initiated a multidisciplinary study of the North Caribou Lake greenstone belt, located some 100 kilometres north of Pickle Lake, in response to increased exploration interest in the gold potential of the belt. Field studies were carried out by the Mineral Deposits (metallogeny), Precambrian Geology (bedrock geology), and Engineering and Terrain Geology (surficial geology) Sections from 1984 through 1986. Interim results of these investigations have already been published as preliminary maps and Summary of Field Work reports, and final results will be presented in a comprehensive report currently being assembled by F.W. Breaks.

This report contains descriptions of mineral occurrences in the greenstone belt, a brief discussion of the metallogeny of the belt, and suggestions for further exploration. It has been issued now, separate from the final report, to meet the urgent requests of explorationists interested in these data. Much of the information presented herein will also be integrated into the final report.

The amount of detail in each property description reflects the amount of field work that was done on the occurrence during this study, and does not necessarily reflect the economic potential of the immediate area. In most cases, the amount of work done was predicated by the amount of outcrop, the complexity of the geology, and the past exploration history of the occurrence. The gold occurrences are described in alphabetical order, based upon the 1986 ownership of the

properties. These descriptions are followed by a brief discussion of the platinum - palladium potential of mafic and ultramafic metaplutonic rocks of the area, as exemplified by one occurrence at Karl Lake.

The locations of all the occurrences are shown on Figure 1 (back pocket). The locations, descriptions and analytical results for samples collected and analysed for gold are shown on Maps 1, 2 and 3 (back pocket) and on tables and figures throughout the text.

The descriptions of the North Rim, Randall Lake, Teal and Agutua Arm/Pyrotex properties in the report are based on detailed field work by the senior author, whose prime responsibility in the multidisciplinary program was to document the metallogeny of the greenstone belt. All of the other property descriptions and discussions are based on limited detailed field work by F.W. Breaks, I.A. Osmani, and their assistants, whose prime responsibility was to map the bedrock geology. The exploration work and development histories of the properties in this report are current to the end of 1986.

No attempt is made here to provide a description of the regional geological setting of the mineral occurrences. This will form a significant part of the final report. The reader is referred to previous Summary of Field Work reports (Breaks *et al.* 1984, Breaks *et al.* 1985, Breaks *et al.* 1986) for this regional setting.

PROPERTY DESCRIPTIONS

DOME EXPLORATIONS LIMITED, CANADIAN NICKEL COMPANY, ESSO MINERALS CANADA LIMITED AND LACANA MINING CORPORATION (MUSSELWHITE PROPERTY)

Location, Ownership and Development

In 1962, W.H. (Harold) and A.L. (Al) Musselwhite, prospectors employed by Kenpat Mines Limited, discovered gold in several locations in the Opapimiskan Lake area (Kenpat No. 1 Vein, the Northwest Showing, the Musselwhite No. 1 and No. 2 Showings and the Everway Showing - Figure 1; back pocket). At the same time, Rio Tinto Canadian Exploration Ltd. encountered gold mineralization near the Paseminon River, just west of Zeemal Lake (Hall 1963, Thurston *et al*. 1979). From 1962 to 1967, Kenpat Mines Limited carried out geological mapping, trenching, prospecting, a ground magnetometer survey and a diamond drill program (8 holes totalling 398 m; Assessment Files Research Office, Ontario Geological Survey, Toronto) on the occurrences in the Opapimiskan Lake area. The property was restaked in 1973 by A.L. and W.H. Musselwhite. In 1974, Noranda Mines Limited completed geological mapping of 6 of 20 claims in the vicinity of the gold occurrences. Ensuing work was financed by several joint venture partners. In 1974 and 1975, Dome Exploration Limited, Canadian Nickel Company, Esso Minerals Canada Limited and Lacana Mining Corporation carried out a diamond drill program (16 holes totalling 1012 m). Between 1976 and 1983, an extensive drilling program was carried out by this joint

venture group (Mineral Deposit Inventory Record, Geoscience Data Centre, Ontario Geological Survey, Toronto).

Development work by the joint venture in 1984 involved the excavation of a decline and a cross-cut designed to better expose the geology and gold mineralization of the West Anticline Zone (The Northern Miner, February 9, 1984). The decline was allowed to flood in 1985.

In 1986, Dome Mines Limited announced the completion of 22,860 m of drilling in the Snoppy Lake area, situated 2.5 km east of the Musselwhite Prospect (The Northern Miner, December 22, 1986). Here, two mineralized zones have been discovered, which together are estimated to contain 2.2 million tons grading 8.2 g/ton gold.

General Statement

Detailed descriptions of the lithologies, structure and metamorphism of the Opapimiskan Lake Property are given by Hall and Rigg (1986). The following descriptions are based on limited detailed mapping conducted by the authors near the gold showings.

Mineralization

Gold mineralization on the Musselwhite Property (Figure 3) is associated dominantly with disseminated sulphides in ironstones, and, to a lesser extent, with quartz-sulphide veins hosted within ironstones and mafic volcanics. Significant gold values are also associated with pegmatitic dikes that are rich in garnet, tourmaline and albite. The surface showings are all hosted within an ironstone unit referred to as the Southern Ironstone (Plate 1a).

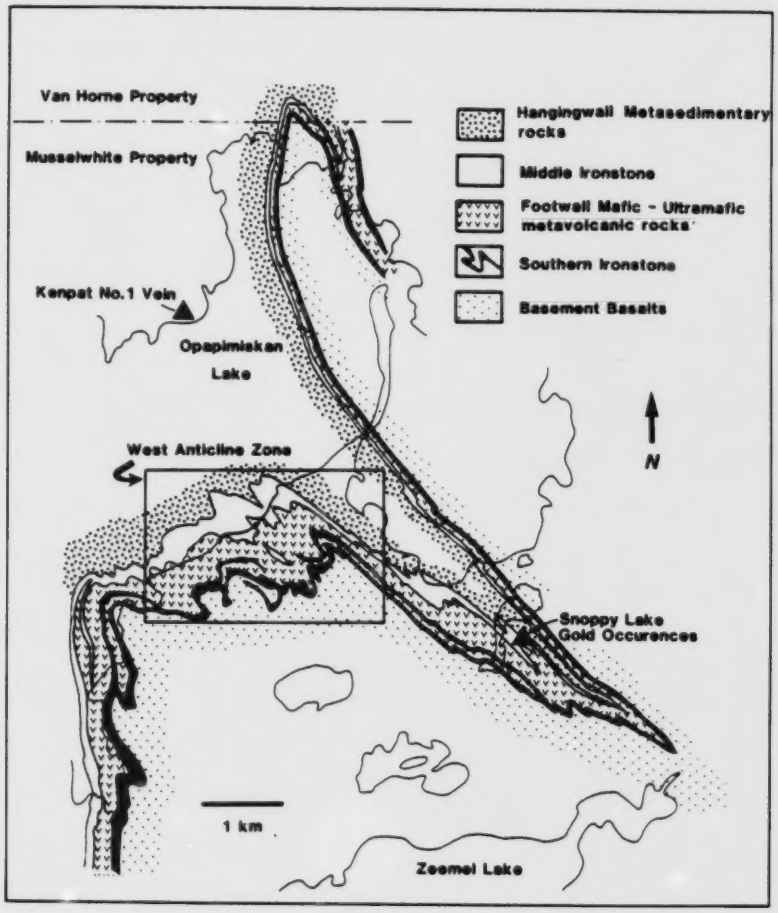

Figure 2. General geology and gold occurrences in the Opapimiskan Lake area (after Hall and Rigg 1986).

Mineralization occurs mainly at or near the crests of complex regional folds (*i.e.* West Anticline Zone and Snoppy Lake Zone, Figure 2), with lesser amounts occurring within isolated shear zones or zones of brittle fracturing (Kenpat No. 1 Vein, Figure 2).

Although stratabound in nature, most of the disseminated and vein-type sulphide mineralization in the ironstones occurs along or parallel to the regional, northwest-trending foliation, which is axial planar to the folds described above. The mineralization is interpreted to be

contemporaneous with, or slightly younger than, this regional foliation (Hall and Rigg 1986).

The geometry of the ironstone units and the mineralized zones has been complicated by superimposed deformation, which is poorly understood. Dome and basin fold patterns in outcrops of ironstone, and relatively undeformed quartz veins parallel to regional foliation, suggest that the direction of the compressive stress responsible for the later deformation was coaxial with the regional foliation.

Mineralization is here described for three occurrences on the Musselwhite Property: the West Anticline Zone, the Musselwhite No. 1 Showing, and the Kenpat No. 1 Vein.

West Anticline Zone

In the West Anticline Zone, gold mineralization occurs mainly along the hanging-wall contact of an ironstone (the Middle Ironstone Unit of Hall and Rigg (1986)) with a structurally overlying, 5.0 m thick, garnet-biotite metapelite horizon (Figures 2, 3 and 4). Most of the mineralization is within the Middle Ironstone Unit. The metapelite is part of the 220 m thick, Hangingwall Metasediments unit of Hall and Rigg (1986). The mineralized Middle Ironstone Unit and the metapelites are not exposed on surface.

Hall and Rigg (1986) describe two types of gold mineralization at the West Anticline Zone:

1) pyrrhotite-bearing quartz veinlets parallel to axial planar foliation, and

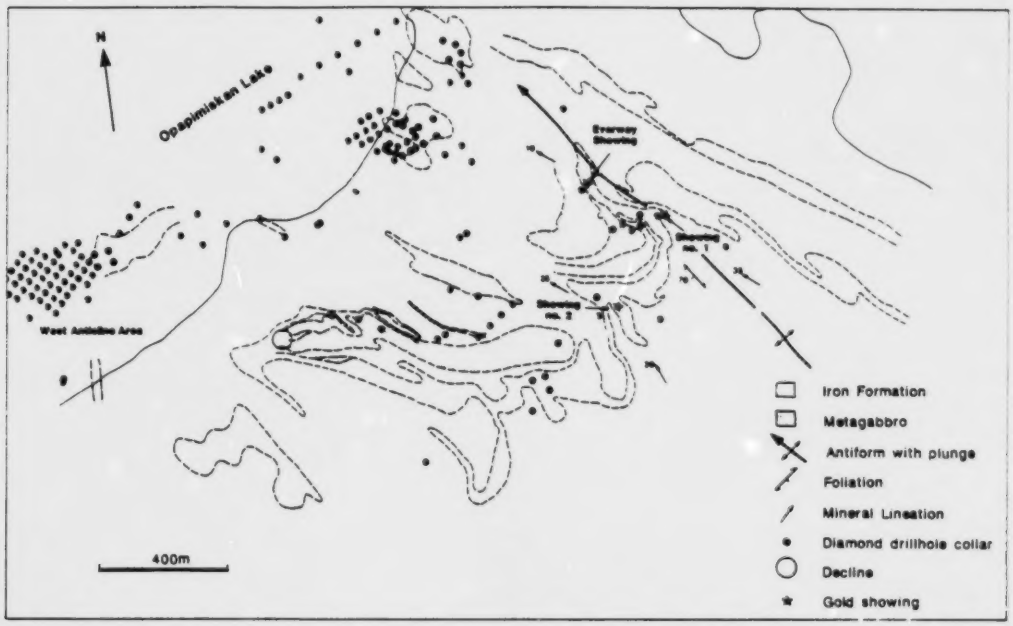

Figure 3. Surface geology and gold occurrences of the Musselwhite Property (after Andrews, Sharpe and Janes 1981).

2) zones of disseminated mineralization in the Middle Ironstone Unit.

Type 1, which is a minor component of gold mineralization in the West Anticline Zone, is characterized by 1 to 5 cm wide veinlets consisting primarily of saccharoidal, blue-grey quartz and massive, medium grained pyrrhotite, with lesser amounts of albite, almandine garnet and calcite, minor arsenopyrite, galena, sphalerite and scheelite, and rare pyrite, chalcopyrite, native gold, and altaite (Plate 1b, c).

Type 2 mineralization is the dominant style, and correlates with grunerite + garnet-rich parts of the Middle Ironstone Unit. It occurs as

lenses elongated parallel to the northwest plunge of the regional fold axes (Figure 4, and Hall and Rigg 1986). These mineralized zones, which transgress bedding in the host rock, are composed of finely disseminated pyrrhotite and rare arsenopyrite, with anomalous amounts of calcite, albite and biotite, in addition to grunerite and garnet (Plate 1d). Most of the gold occurs as microscopic inclusions in pyrrhotite grains (Hall and Rigg 1986).

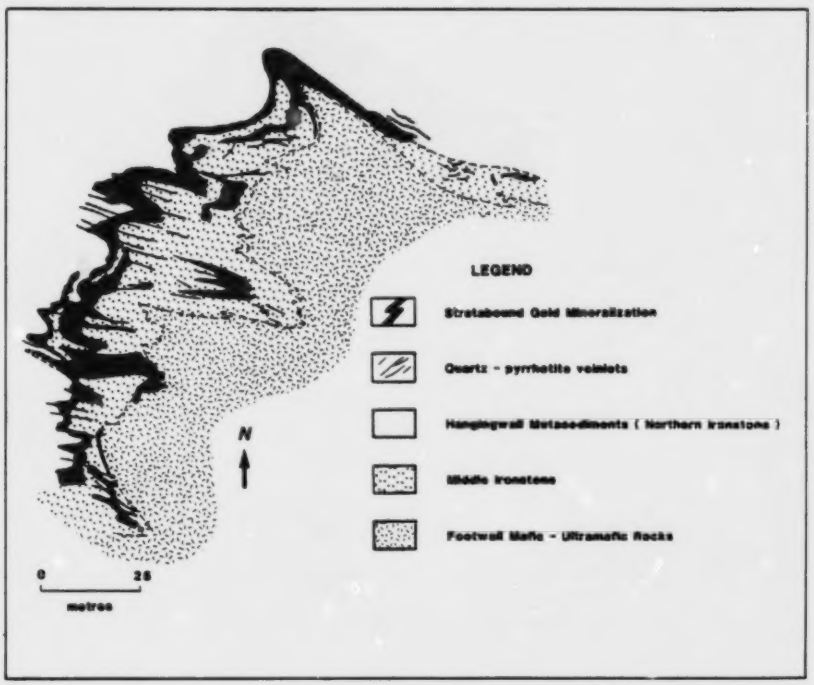

Figure 4. Geology and distribution of gold mineralization on the 215 m level, West Anticline Zone (after Hall and Rigg 1986).

Musselwhite No. 1 Showing

Three other mineralization types are recognized at the Musselwhite No. 1 Showing: (1) shear zone-hosted, (2) albite pegmatite dike-hosted, and (3) metsomatic selvages along the margins of the pegmatite dikes.

Mineralization in shear zones was described from the Musselwhite No. 1 Showing by Burns (1963), who reports high assay values but presents no data. Thurston *et al.* (1979) report a grab sample value of less than 1000 ppb gold. Three significant gold values, up to 6.7 ppm, were obtained in this study (Table 1). Sulphide mineralization at this occurrence is associated with a 1.0 to 1.8 m wide siliceous breccia of BIF within a shear zone. The shear zone is parallel to the northwest-trending axial surface of the regional folds. The zone contains 5 to 15% disseminated pyrrhotite, pyrite and arsenopyrite, together with pyrrhotite veinlets (1 to 5 mm wide), which occur mainly as an interconnecting vein system.

Gold assays associated with albite pegmatite dikes range from 600 to 1840 ppb (Table 1). The dikes at the Musselwhite No. 1 Showing cut mafic volcanics and the Southern Ironstone (Plate 1e). They range in width from 2.5 cm to 20 cm, are porcellaneous to light pink on a weathered surface, and are typically massive and allotriomorphic granular in texture. They contain 80 to 90% anhedral, white to light blue-grey albite, and 10 to 20% grey quartz, which occurs as ovoid, anhedral grains up to 0.5 by 1.0 cm in size and as irregular masses up to 2.5 by 4 cm in size concentrated near the dike centres. Minor accessory minerals include tourmaline, chlorite and garnet. Black tourmaline occurs as scattered, subhedral, fine to medium grained crystals and as irregular, lensoid masses near the dike margins.

Assays of mineralization from metasomatic selvages along contacts of the albite pegmatite dikes range from 15 to 1740 ppb (Table 1).

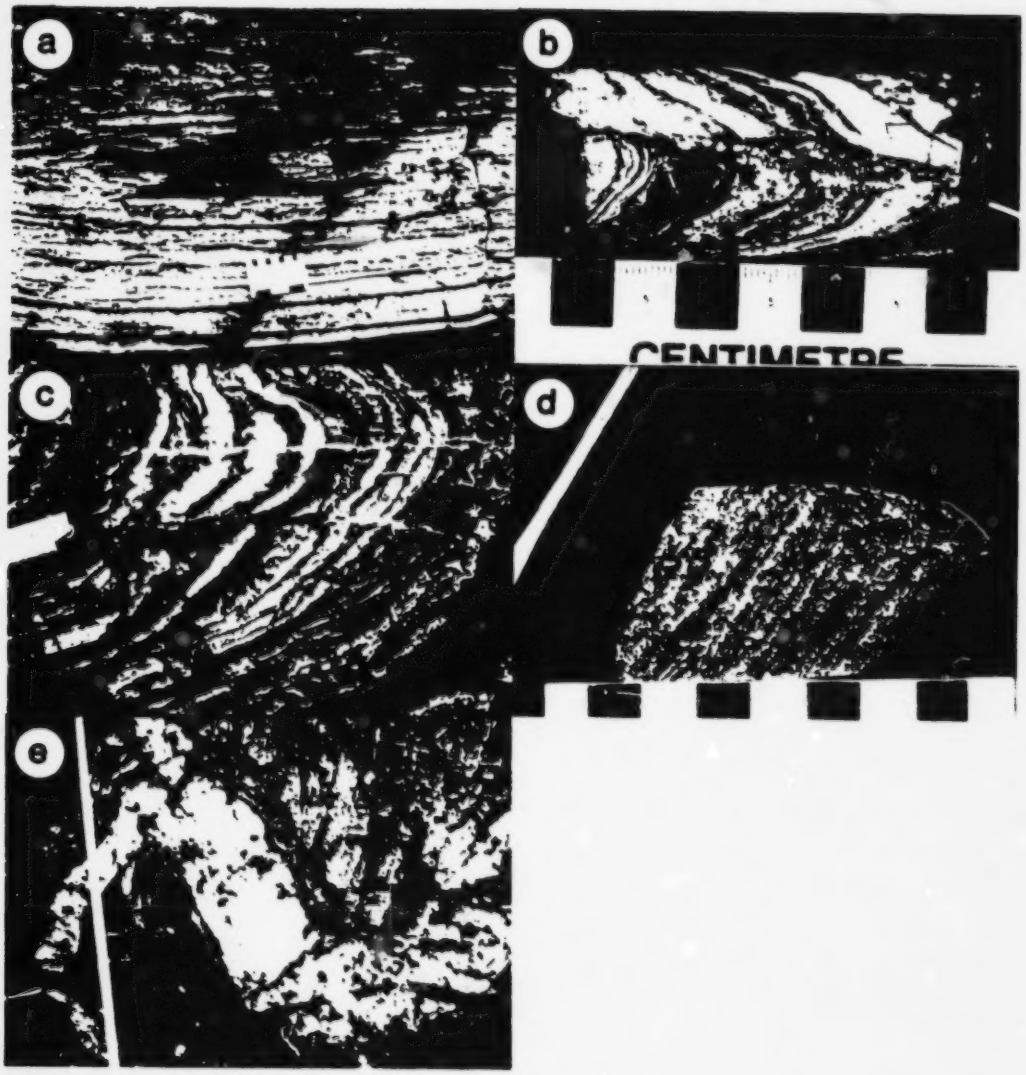

Plate 1. Lithologies and mineralization types at the Musselwhite Property. All photographs courtesy of R.S. Hall, Geologist, Esso Minerals Ltd., Toronto.

Brown weathered, metasomatic selvages to the pegmatite dikes are especially notable when the host rocks are mafic volcanics. These selvages are typically 3 to 5 mm wide, but widen considerably (up to 15 cm) within dilation zones associated with boudins. Selvages in mafic volcanics are composed primarily (90%) of fine to medium grained biotite and chlorite, with minor amounts of black tourmaline, garnet and arsenopyrite. Relatively high concentrations of medium to coarse grained, anhedral pyrite (5-10%) may be localized within boudin necks.

Chlorite is the dominant selvage mineral (70-80%) where the dikes intrude BIF. Tourmaline is present in these selvages in amounts up to 20%, and scattered disseminated arsenopyrite and pyrrhotite may be present locally.

The gold values obtained from both the pegmatite dikes and the selvages show a clear relationship with anomalous levels of rare metals, in particular Li, Rb, and Ta (Table 1). Also noteworthy are anomalous Sb levels in the dikes and selvages. Arsenic is also distinctly anomalous in all material analyzed.

(a) Outcrop of typical chert-grunerite BIF of the "Southern Ironstone Unit" (West Anticline Zone). (b) Drill core sample of a quartz-pyrrhotite-garnet vein, typical of the vein-type mineralization at the West Anticline Zone, cross-cutting the bedding of chert-grunerite BIF. (c) Outcrop showing quartz-pyrrhotite veins cross-cutting the crest area of an open fold in chert-grunerite BIF (West Anticline Zone). (d) Drill core sample showing disseminated pyrrhotite (pale mineral) concentrated along foliation surfaces of intensely sheared BIF, typical of the disseminated-type mineralization (West Anticline Zone). (e) Outcrop showing an albite-rich granitoid dike cross-cutting mafic volcanics at the Musselwhite No. 1. Showing.

Table 1. Analyses of mineralized shear zone, albitic granitoid dike, tourmaline-chlorite-biotite metasomatic segregation, quartz vein, and unmineralized BIF from the Musselwhite No. 1 gold showing. Analyses by the Geoscience Laboratories, Ontario Geological Survey, Toronto.

	Au (ppb)	Ag (ppm)	As (ppm)	Sb (ppm)	Cu (ppm)	Pb (ppm)	Zn (ppm)	Li (ppm)	Sn (ppm)	Rb (ppm)	Ta (ppm)	Nb (ppm)	F (ppm)	B (ppm)	Nb/Ta	Na_2O (%)	K_2O (%)
Albitized granitoid dike																	
OP153-1B	1840	<2	19	0.6	225	11	24	66	<0.8	215			100	17			
-1D	790	<2	1050	5.2	144	18	82	71	0.9	120			130	21			
-1S	600	<2	23	2.8	13	<10	33	34	87.1	230	140	14	670	5	0.1	4.61	0.53
-1T	310	<2	2.0	1.9	5	<10	8	26	38.6	145	80	12	320		0.15	3.88	0.22
Tourmaline-chlorite-biotite selvages																	
OP153-1C	310	<2	47	1.3	24	<10	98	375	18.5	980			4160	41			
-1U	1740	<2	6500	55	13	<10	96	49	309	16	80	15	5240	330	0.18	0.19	0.27
Shear zone, mineralized with asp, po, py along metavolcanic/BIF contact																	
FWB-25-0002	2720	<2	50	1.7	(1.8 metre channel sample across shear zone)												
OP153-1X	5950	2	57	2.8	148	96	41										
1Z	340	<2	61	2.2	41	<10	62										
1W	6710	<2	2300	13.9	302	<1	38										
Quartz vein, concordant to foliation																	
OP153-1R	980	<2	5	1.5	7	<10	26										
Unmineralized grunerite-magnetite-chert BIF																	
FWB-885-0002	2720	<2	10	3.6	(12.5 m channel sample taken across uniformly banded but not intensely folded BIF adjacent to mineralized shear zone (c.f. FWB 85-0002). Possibly representative of background.)												

Kenpat No. 1 Vein

The Kenpat No. 1 Vein, or Northwest Showing, is located near the northwestern shore of Opapimiskan Lake (Figure 2) and was discovered in 1962 by the Musselwhite brothers (Thurston *et al*. 1979). It was first investigated by Kenpat Mines Limited, which excavated 18 trenches and sank 12 diamond drill holes totalling 773 m (Thurston *et al*. 1979).

Thurston *et al*. (1979) state that the Kenpat No. 1 Vein is hosted within "a single northwest-striking band of iron formation." However, this type of host rock was not observed by the present survey, nor has it been identified by other workers in the area (*e.g*. H. Hodge, President, Van Horne Gold Exploration, personal communication, 1985). Burns (1963) indicates that the northwest-striking, 11,000 gamma, magnetic high in the vicinity of the vein is due to magnetite-bearing andesite. Foliated, locally pillowed, mafic volcanics constitute the immediate host rock for the vein (Figure 5). The pillows are typically flattened and have dark green to rusty brown, 0.5 cm to 2 cm wide selvages that contain local concentrations of biotite and garnet.

The vein consists of massive to locally lineated, milky white quartz and is at least 210 m long and 1.0 to 6.1 m wide. It contains less than 1%, fine to medium grained, crystalline pyrite, chalcopyrite and arsenopyrite. Masses of medium to coarsely crystalline, black tourmaline are locally present in amounts up to 10% near the vein's southeastern contact near Trench 4. Light brown, Fe-carbonate occurs as local blebs in amounts up to 5%. In Trench 5, a carbonate-rich breccia zone at least 2.0 m wide is exposed, containing 20-30% elongate quartz lenses in a medium crystalline, Fe-carbonate matrix (Figure 5).

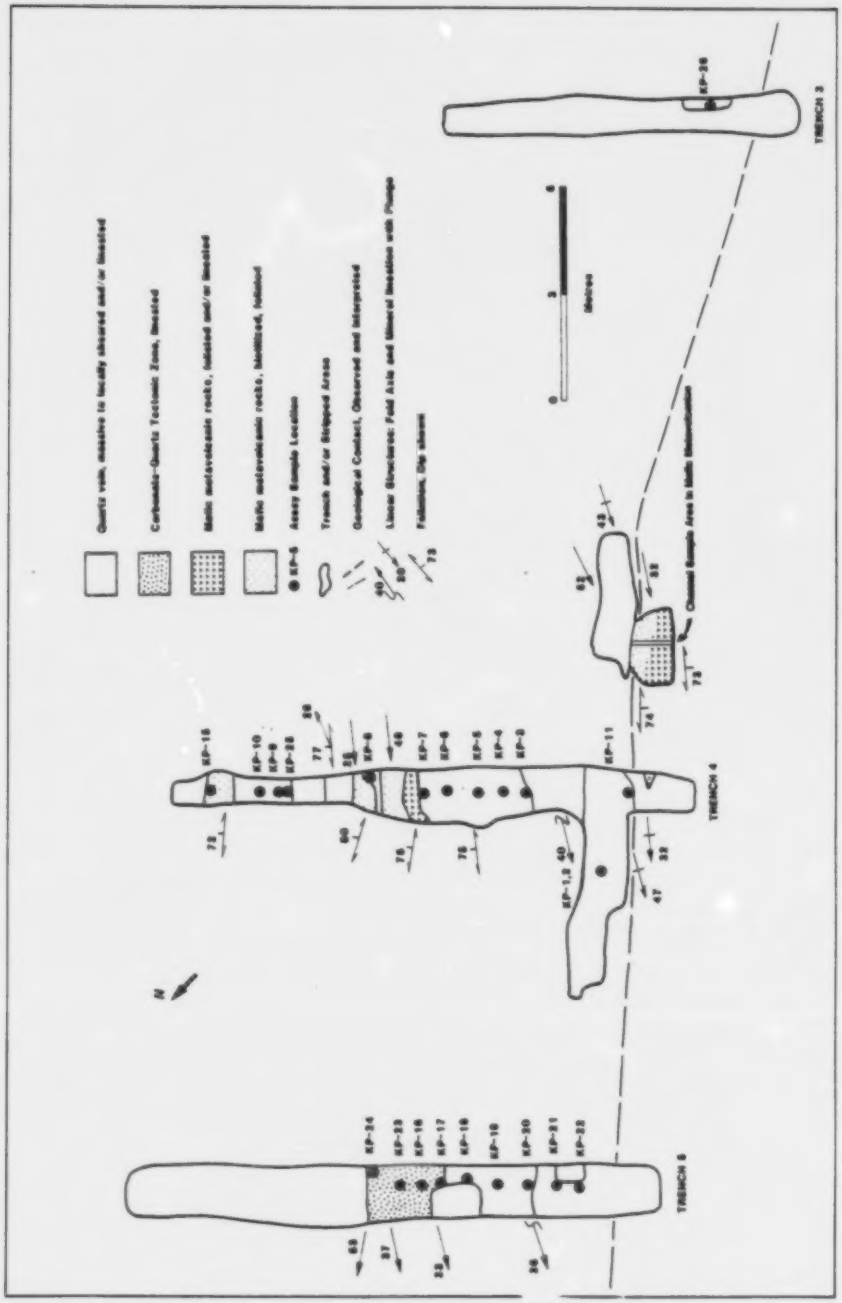
Quartz vein, massive to locally sheared and/or fractured
Carbonate-Quartz Tectonic Zone, Fractured
Mafic metavolcanic rocks, foliated and/or fractured
Mafic metavolcanic rocks, Unaltered, Jointed
Assay Sample Location
Trench and/or Stripped Areas
Geological Contact, Observed and Interpreted
Linear Structures: Fold Axis and Mineral Lineation with Plunge
Foliation, Dip shown
Meters
Channel Sample Area in Mafic Metavolcanics
TRENCH 3
TRENCH 4
TRENCH 5
N

Figure 5. General geology of the Kenpat No. 1. Vein, showing sample locations.

A 0.6 m wide, well foliated, biotite-rich alteration halo is exposed adjacent to the vein's contacts near Trench 4 (Figure 5). Irregular (folded) quartz-chlorite veinlets less than 5 mm wide typically occur within this zone.

The highest gold values obtained from surface sampling of the Kenpat No. 1 Vein are 8.0 g/t over 5.5 m and 8.0 g/t over 6.1 m (The Northern Miner, December 6, 1962). The highest gold value obtained by the drill program conducted by Kenpat Mines Limited was 13.4 g/t over 0.4 m. Analytical results obtained during this study for samples from Trench 4 include values as high as 1600 ppb and 3500 ppb, but most assays are significantly lower than reported in previous sampling.

A 1.65 m wide section of mafic volcanics, exposed adjacent to the southwestern contact of the vein between Trenches 3 and 4, was sampled at 10 cm intervals during this study and analysed for Au, Ba, R, K_2O and As. These analyses (Figure 6, back pocket) indicate insignificant enrichment in gold (5 to 20 ppb), but significant enrichments in Ba, R, K_2O and As within 1 m of the vein.

LEGION RESOURCES LIMITED (LIBERT LAKE PROPERTY)

Location, Ownership and Development

The Libert Lake property is located approximately 3.5 km south of the southern tip of Opapimiskan Lake, and 3.0 km north of Barrigar Lake (Figure 1, back pocket). The property consists of 45 claims which were staked during 1980 and 1982 by 498217 Ontario Limited. This company carried out geological and geophysical surveys, geochemical sampling, stripping and trenching (Assessment Files Research Office, Ontario Geological Survey, Toronto).

Geology

Description of Lithologies

Mafic volcanics: The property is underlain predominantly by massive, fine grained, mafic volcanics and amphibolite (Figure 7). The latter typically consists of variable amounts of actinolite, hornblende, plagioclase, chlorite and calcite. In addition, a medium to coarse grained, hornblende porphyroblastic unit is present in the northwestern portion of the property, and a garnet-bearing unit occurs adjacent to iron formation in the central portion of the property, immediately east of an unnamed lake.

Ultramafic volcanic rocks: Rocks interpreted to be ultramafic in origin are relatively abundant in the northern portion of the property, and also occur locally as small lensoid units in the southern and central portions (Figure 7). These rocks are distinguished from the

central portions (Figure 7). These rocks are distinguished from the mafic volcanics by their emerald green colour, a lack of plagioclase, and the presence of serpentine-altered minerals. The unaltered rocks consist mainly of actinolite, with minor chlorite, tremolite and carbonate. Alteration assemblages include talc + actinolite + phlogopite, and carbonate + serpentine + tremolite. Altered rocks are gradational with the unaltered varieties.

Figure 7. Geology of the Libert Lake area.

In the northeastern portion of the property, a magnetite-hornblende-carbonate unit occurs close to the granitic contact. This unit contains an unusually high amount of magnetite (up to 30%).

Felsic to intermediate volcanic rocks: Fine grained, massive rocks of intermediate to felsic composition occur in the northeastern portion of the property (Figure 7), in contact with the magnetite-rich ultramafic unit. These rocks are composed dominantly of quartz and plagioclase.

Clastic sediments: Wacke and pelite are intermittently exposed throughout the property. Wacke is the predominant rock type in the northwestern region, where it is interbedded with garnet-bearing pelite and amphibole + biotite-bearing rocks of probable sedimentary origin. In the southern portion of the property, along the eastern shore of Libert Lake, the wackes are fine to medium grained, grey to greyish-white and are composed of biotite + quartz + feldspar + muscovite + pyrite. Euhedral garnet porphyroblasts were also observed locally in the biotite + quartz-rich matrix of the wackes.

Chemical sediments: An approximately 75 m thick, north-trending unit of iron formation is traceable for 2.2 km in the north-central portion of the property (Figure 7). This unit consists of banded chert and magnetite-grunerite, with grunerite-rich bands present in areas where the iron formation is adjacent to granitic dikes. Individual bands vary from a few millimetres to several centimetres thick.

Granitic intrusive rocks: The volcanic-sedimentary sequence underlying the Libert Lake Property is bounded to the east by gneissic

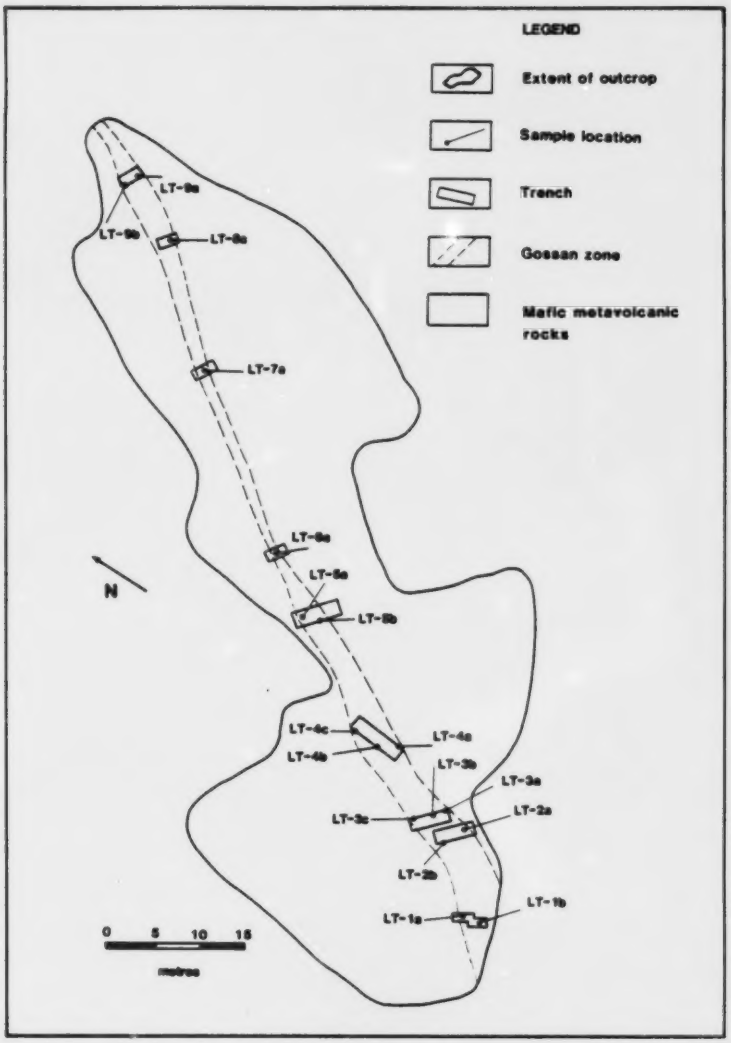

Figure 8. Detailed geology of the L-1 Showing, Libert Lake Property.

to massive tonalite, and to the west, by granite, leucogranite and trondhjemite (Figure 7). In addition, a stock and several dikes of tourmaline-bearing granodiorite intrude the sequence in the central portion of the property. The stock is approximately 3 km long (north-south), and 75 m to 235 m thick, and is interpreted to be the product of the anatexis of metasedimentary rock because of the presence of

muscovite-rich inclusions, the overall abundance of muscovite (15% average) and the presence of garnet. The age of this rock type relative to the surrounding granitic batholiths is unknown.

Structural Geology

Common to all lithologies on the property are a moderately to intensely developed foliation and an equally well developed stretching lineation. The foliation, which dips steeply (70° to 80°) to the northwest and trends parallel to the greenstone boundaries, is defined by the parallel orientation of: amphiboles and chlorite in the volcanic rocks; quartz, muscovite and biotite in the clastic sediments, and flattened quartz and plagioclase aggregates in the flanking granitic rocks. On the northeastern shore of Libert Lake, metamorphic mineral banding (quartz- and biotite-rich) within tonalite is parallel to the foliation described above. In general, stretching lineations trend north-south to southwest and plunge steeply (60° to 85°) to the south-southwest.

Closed to tight, southwest-plunging (40° to 50°), mesoscopic, intrafolial folds of dominantly S-asymmetry occur in the chert-magnetite BIF unit exposed immediately east of an unnamed lake in the central portion of the property. Quartz veins and muscovite + garnet-bearing granitic dikes, present throughout the volcano-sedimentary sequence, also display asymmetric folds of a similar attitude. The foliation described above is axial planar to the asymmetric folds.

Table 2. Selected assay values for samples from the Libert Lake area. Sample numbers correspond to location numbers on the Figure 8. Gold values are given in ppb and other elements are given in ppm. All analyses by the Geoscience Laboratories, Ontario Geological Survey, Toronto.

Sample	Description	Au	Ag	As	Co	Cr	Cu	Ni	Pb	Zn	Sb
LT-1a	Sheared host rock (mafic metavolcanic), intense rusty weathering, up to 5% sulphides	65	<2	130	37	372	143	118	<10	180	2.4
LT-1b	Sheared host rock + rust stained quartz vein, no visible sulphides	1640	<2	400	6	82	62	20	27	100	3.5
LT-2a	Sheared host rock, intense rusty weathering, minor sulphides	195	<2	680	40	338	230	126	10	335	5.6
LT-2b	Sheared gossan zone, no visible sulphides	1350	<2	83	<5	52	56	<5	<10	220	1.3
LT-3a	Sheared host rock, no visible sulphides	390	<2	270	43	383	144	128	<10	68	3.8
LT-3b	Sheared quartz veins/veinlets, rusty weathering	1770	<2	365	9	28	96	16	<10	88	1.9
LT-3c	Sheared host rock, intense rusty weathering	760	<2	250	18	995	520	85	21	310	2.8
LT-4a	Sheared host rock, intense rusty weathering, up to 7% sulphides (pyrite and pyrrhotite)	415	<2	83	56	535	475	355	<10	1220	1.8
LT-4b	Sheared quartz veinlets, no visible sulphides	19	<2	56	<5	<10	18	<5	10	8	0.4
LT-4c	Intensely sheared host rock + quartz veinlets, sulphides	190	<2	305	59	1650	58	265	26	85	4.4
LT-5a	Sheared, rust-stained quartz vein/veinlets	310	<2	730	31	342	395	83	<10	405	3.5
LT-5b	Sheared host rock + quartz vein/veinlets	980	<2	420	42	810	152	182	<10	445	3.3
LT-6a	Quartz vein shear zone, intense rusty weathering	130	<2	375	12	425	188	56	<10	455	2.8
LT-7a	Sheared gossan zone, minor sulphides	110	<2	150	28	257	280	120	<10	155	2.5
LT-8a	Sheared quartz vein, gossan zone, no visible sulphides	1170	<2	1400	25	1620	450	167	335	360	6.9
LT-9a	Sheared, rust-stained quartz vein, no visible sulphides	800	<2	4500	15	1580	230	30	<10	235	8.6
LT-9b	Sheared host rock, intense rusty weathering, up to 2% sulphides	880	<2	185	190	6150	240	635	<10	315	22.1
LT-10	Muscovite-bearing granitic pegmatite	20	<2	3.5	<5	<10	39	<5	23	63	0.6
LT-11	Metasomatic halo (grunerite + chlorite + tourmaline) between chert-magnetite BIF and muscovite-bearing granitic pegmatite	13	<2	2.5	<5	<10	<5	<5	<10	88	0.3
LT-12	Gossan zone within banded iron formation, adjacent to muscovite ± tourmaline-bearing trondhjemite dike	11	<2	2.5	<5	<10	26	<5	21	50	0.3
LT-13	Gossan zone in chert-magnetite BIF	14	<2	1.5	<5	<10	14	<5	26	74	0.2
LT-14	Gossan zone in ultramafic metavolcanic adjacent to garnet-muscovite-bearing trondhjemite	37	<2	170	<5	41	78	10	<10	210	0.8

Mineralization

One significant gold occurrence, the L-1 Showing, is present on the Libert Lake Property (Figure 7). This showing is within an intensely foliated and oxidized, 010°-trending shear zone developed in mafic volcanic rocks (Figure 8). This zone is approximately 1120 m long and 4 m wide and typically contains up to 1% disseminated pyrite and pyrrhotite and numerous, foliation-parallel, quartz + Fe-carbonate + sulphide veinlets. Gold is intimately associated with the sulphides in both the veins, where up to 7% pyrite and pyrrhotite may be present, and the wallrock. To date, the highest gold value obtained from the zone is 5.1 g/t over a width of 2.7 m, obtained by 498217 Ontario Limited. Grab samples taken during this study, from old trenches, returned gold values up to 1770 ppb (Table 2).

The L-2 Showing (Figure 7) was not examined in this study, but values of 3.6% Cu and 1135 ppb gold have been reported from it (Assessment Files Research Office, Ontario Geological Survey, Toronto). Samples taken during this study from other locations on the Libert Lake Property yielded insignificant gold values (Figure 7 and Table 2).

MOSS RESOURCES LIMITED
(AGUTUA ARM PROPERTY)

Location, Ownership and Development

The Agutua Arm Showing (Figure 1; back pocket) was originally staked in 1967 by Pyrotex Mining and Exploration Company, which drilled 3 diamond drill holes totalling 264 m and carried out trenching and stripping before allowing the claims to lapse. The showing was restaked (15 claims) in 1984 by 428226 Ontario Limited, which was acquired by Moss Resources Ltd. later in that year.

Geology

The Agutua Arm Property is underlain predominantly by massive, mafic to intermediate, volcanic rocks intruded locally by biotite trondhjemite and mafic dikes. Several east-trending (080°) zones of quartz-Fe carbonate-sericite schist, up to 3 m wide, cut the mafic metavolcanics. Penetrative planar fabrics are absent or are only weakly developed outside the schistose zones.

Mineralization

On the northeastern shore of Agutua Arm, gold mineralization occurs in a set of *en echelon*, quartz-arsenopyrite-pyrite-chalcopyrite veins up to 25 cm wide within a 1-3 m wide, east-trending, quartz-Fe carbonate-chlorite bearing zone (Figure 9). The carbonate-bearing rock grades into massive, actinolite-rich, mafic volcanics over a distance of less than 25 cm.

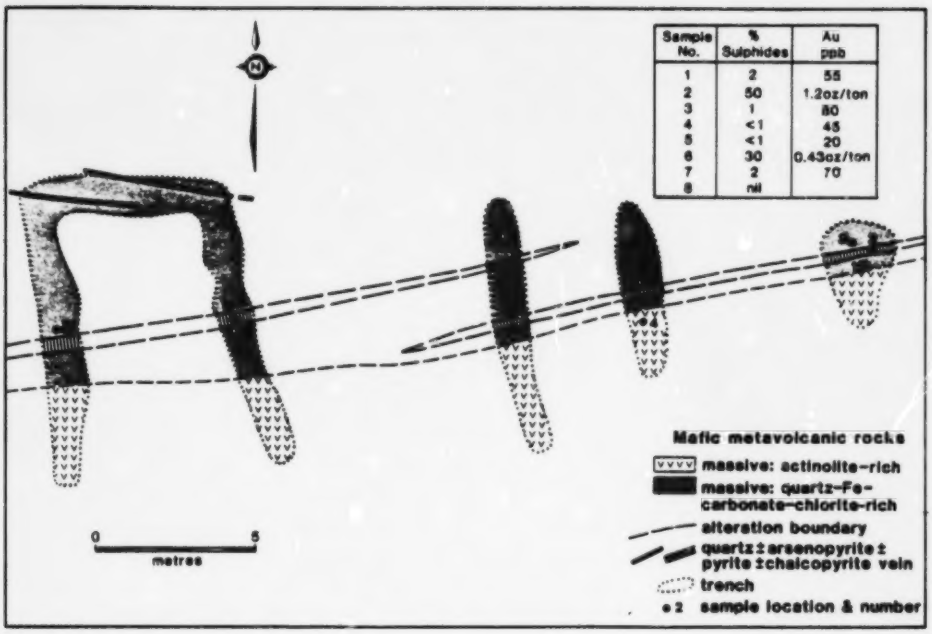

Figure 9. Detailed geology of the Agutua Arm (Pyrotex) Showing.

The vein set can be traced for 25 m along strike. Veins, which typically overlap in a right-handed sense, dip vertically and consist of massive quartz with minor disseminated pyrite, arsenopyrite and chalcopyrite, and localized pods of massive arsenopyrite and chalcopyrite. Minor (less than 5%) chalcopyrite and pyrite occur intergrown with arsenopyrite in the massive pods. Gold values, obtained from grab samples taken by the authors in 1985 (Figure 9), are highest within the arsenopyrite pods (up to 43 ppm, 1.3 oz/ton). Quartz veins that are relatively barren of sulphides and the silicified wallrock both returned insignificant gold values (25 to 80 ppb).

Bartlett *et al.* (1985) described a sulphide-bearing shear zone on an island near the mouth of the North Caribou River as:

> *"A 13 cm wide shear zone mineralized with sphalerite, pyrite and chalcopyrite was discovered during this survey. The shear zone which strikes 120° and dips 67° northeast is characterized by well defined deformation banding. It is composed of 0.3 - 2.5 cm wide quartz-brown carbonate layers alternating with 1 - 1.5 cm wide, dark green layers rich in fine grained chlorite. The shear zone is localized along a contact between deformed intermediate volcanics and a mafic dike. Mineralization occurs in two different modes:*
>
> *1) sphalerite-pyrite-chalcopyrite in quartz-carbonate layers concordant to foliation; and*
>
> *2) galena-pyrite in later, cross-cutting, calcite-rich veins (1-15 cm width). Native silver occurs as rare, thin, irregular fine grained flakes up to 2 mm across. Assays of mineralized material show silver contents between 70 and 100 g/t and indicate very low Au/Ag ratios (<0.4 x 10^{-3}). Ag content increases proportionally with Zn content, thus, other than in the rare occurrences of native silver, most Ag is probably contained within sphalerite".*

MOSS RESOURCES LIMITED
(RANDALL LAKE PROPERTY)

Location, Ownership and Development

Moss Resources Ltd. owns a group of 75 claims in the Randall Lake - North Caribou River area (Figure 1; back pocket). The property was originally staked in 1979 by St. Joseph Exploration Ltd., which carried out geological mapping, ground EM and magnetic surveys and limited trenching. Six diamond drill holes, totalling 350 m, were subsequently drilled by St. Joseph Exploration Ltd. to test geologically favourable EM conductors. The claims were allowed to lapse and the property was restaked in 1984 by 452826 Ontario Limited, which was acquired by Moss Resources Ltd. in that same year. In February and March of 1985, Moss Resources Limited carried out VLF-EM and magnetic surveys over the property. In June and July of 1985, geological mapping, stripping and lithogeochemical sampling were carried out by both Moss Resources Ltd. and the Ontario Geological Survey (Piroshco and Shields 1985).

Geology

During the summer of 1985, the senior author conducted detailed mapping in an approximately 4 km^2 area in the Centre Lake region (Figures 1 and 10). This mapping is the basis for the following descriptions. This area forms only a minor portion of the actual Randall Lake Property (Assessment Files Research Office, Ontario Geological Survey, Toronto).

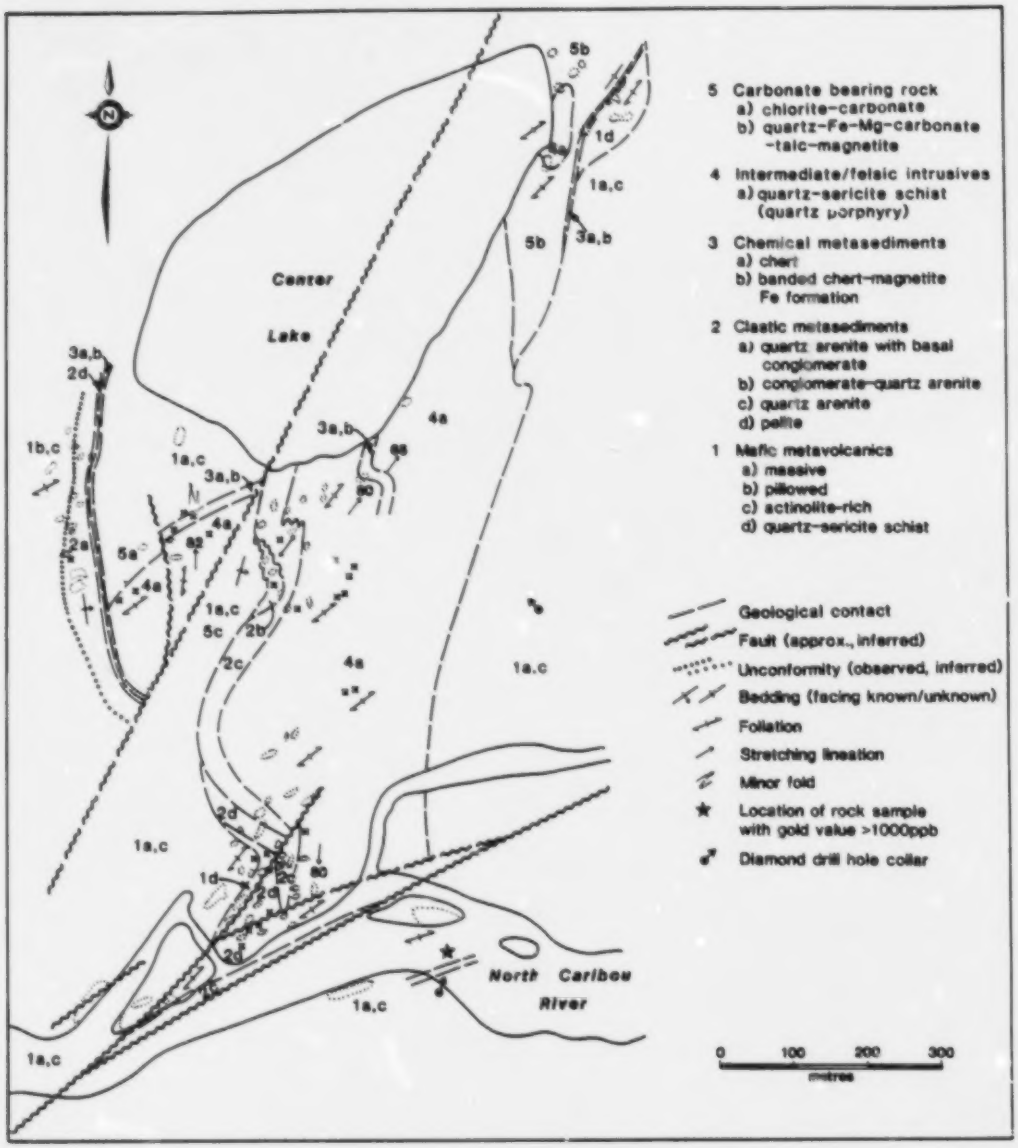

Figure 10. Geology of the Centre Lake area.

Description of Lithologies

Mafic volcanics: Mafic volcanics are the dominant lithology on the property and are typically massive and actinolite-rich. In the area

mapped in detail, pillows were observed only in outcrops west of Centre Lake (Figure 10).

In the Centre Lake region, zones of Fe carbonate-quartz-chlorite-rich mafic volcanics commonly occur at or near contacts with adjacent lithologies (Figure 10). The primary mineral textures, preserved in actinolite-rich areas, are totally destroyed in the carbonate-quartz-chlorite zones. Brecciated, stockwork-like, quartz + Fe carbonate + sulphide veinlets are locally present, especially in outcrops east of Centre Lake.

West of Centre Lake, adjacent to a quartz arenite unit, pillowed mafic volcanics rich in sericite-hematite-chlorite-pyrite (Plate 2a) occur in a zone approximately 3 m thick. The outcrops in this zone show irregularly weathered surfaces characterized by contrasting, bleached and rusty brown weathered patches (Plate 2b). These surfaces have been interpreted as a paleo-regolith by the senior author.

Clastic metasediments: A 25 m wide sequence of metasedimentary rocks is exposed south and west of Centre Lake (Figure 10). It consists of a basal unit of chert pebble conglomerate and quartz arenite up to 5 m thick, a middle unit of massive quartz arenite, and an upper unit of thinly bedded pelites and siltstones up to 3 m thick. The basal conglomerate shows both normal and reverse grading, and contains up to 50% subangular chert clasts to 5 cm in size and rare quartz-sericite schist clasts (Plate 2c) in a matrix of fine grained quartz + sericite + chlorite. The quartz arenite locally exhibits well-developed trough cross-bedding and soft sediment deformation structures (convolute

bedding, load casts), and consists of 95% quartz grains in a sericitic matrix.

Chemical Metasediments: Thinly bedded chert-magnetite BIF occurs as: a 3 m wide unit capping the quartz arenite and siltstone sequence west of Center Lake; a 1 to 3 m wide unit included in quartz porphyry, cropping out south of Centre Lake, and a 1 m wide unit between mafic flows near the northwestern shore of Centre Lake (Figure 10). The latter BIF is highly tectonized and consists of thinly bedded chert, containing up to 30% disseminated pyrite and stilpnomelane, lenses of quartz-Fe carbonate-sericite schist, chlorite schist, local magnetite bands, pods of massive pyrite intermixed with chlorite and quartz, and chalcopyrite seams.

Intermediate to felsic intrusive rocks: Intermediate to felsic intrusive rocks have a bleached appearance on a weathered surface and have been deformed to sericite schists with up to 20% quartz eyes (Plate 2d). These schists show clear cross-cutting relationships with adjacent lithological units. The quartz eyes, ranging up to 1 cm in diameter, may be a single grain or a composite of grains. Dark greyish-green, chlorite-rich quartz porphyry is also present, but its relationship with the dominant, sericite-rich schists is unknown.

At Centre Lake, the porphyry/schist occurs as a north-trending unit, 400 m wide, which is roughly conformable wih the trend of stratigraphic units (Figure 10). The porphyry shows a complex contact relationship with quartz arenite to the west, in which 1-10 cm wide, highly foliated, fault-bounded enclaves of porphyry occur within quartz arenite. South of Centre Lake, a 10 cm wide apophysis of porphyry was

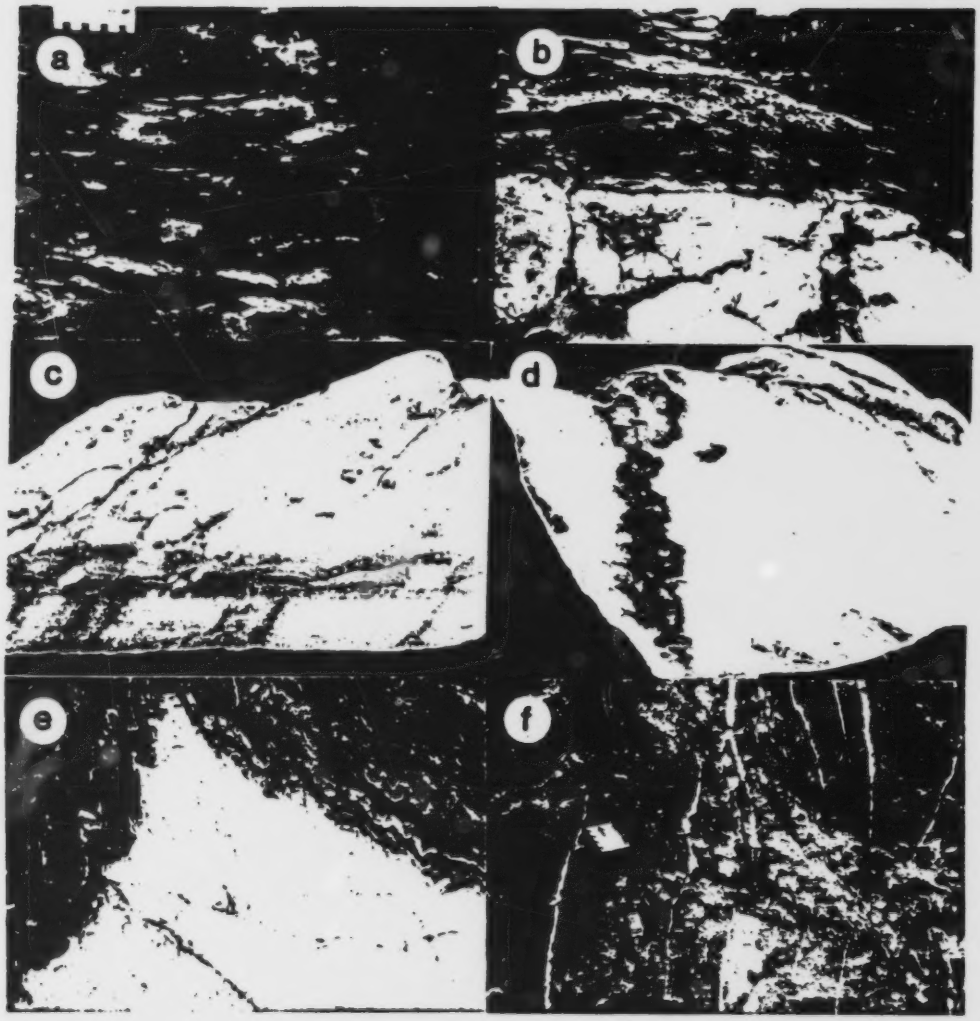

Plate 2. Lithologies in the Centre Lake area.

(a) Outcrop showing Fe carbonate- and sericite-rich pillowed mafic volcanics gradational with the brecciated mafic volcanics shown in (b). (b) Outcrop, located west of Centre Lake, showing in-situ brecciation of pillowed mafic volcanics (regolith), unconformably overlain by chert pebble conglomerate and quartz arenite. (c) Slabbed hand sample of chert pebble conglomerate from an outcrop west of Centre Lake. (d) Slabbed hand sample of quartz porphyry (quartz-sericite schist) from an outcrop east of Centre Lake, showing a folded quartz-tourmaline vein. (e) Outcrop, located south of Centre Lake, showing north-northeast plunging open folds developed in chert-magnetite BIF in contact with quartz porphyry. (f) Outcrop, located east of Centre Lake, showing a quartz-sulphide vein system cross-cutting sulphide-bearing silicified and carbonatized ultramafics.

observed cutting iron formation, suggesting that the porphyry is intrusive in origin. On the eastern shore of Centre Lake, a small porphyry 'plug' intrudes quartz-Fe-Mg carbonate-chlorite schist. The contact is highly irregular, but sharp, and is locally marked by narrow chloritic or quartzose margins up to 1 m wide. Dark grey, talcose inclusions up to 20 cm long are locally present in the porphyry 'plug' and are interpreted to be xenoliths of ultramafic rock. Stockwork quartz + tourmaline veining is also common. Local, rusty weathering patches are interpreted to result from minor amounts of Fe carbonate which occurs in pressure shadows associated with the quartz eyes.

Carbonate-bearing rock: Rusty weathered, quartz-Fe-Mg carbonate-bearing rock is exposed on the eastern shore of Centre Lake (Figure 10). This rock is massive or highly schistose and locally contains well-developed quartz + Fe carbonate + pyrite + arsenopyrite-rich patches. The protolith is unknown, but is interpreted to be ultramafic, because the unit is stratigraphically equivalent with relatively unaltered komatiites exposed to the north. The strike length of the unit is unknown, and its western boundary is hidden by overburden and Centre Lake. The eastern boundary coincides with the contact with a north-trending, massive mafic volcanic rock.

Outcrops of a chlorite-carbonate-rich rock (Figure 10) are exposed south of Centre Lake, but the geometry, extent and protolith of this unit are unknown.

Within the carbonate-bearing rock, the Fe-Mg carbonate occurs in amounts up to 80% as fine-grained, equigranular mosaics of grains with interstitial quartz and small amounts (less than 3%) of chlorite,

sericite, albite, actinolite, biotite and magnetite. Where the carbonate is present in lesser amounts (less than 50%), it occurs as anhedral to subhedral porphyroblasts intermixed with relatively finer crystalline quartz, chlorite, and sericite.

Quartz may be present in amounts up to 45% and occurs as finely crystalline aggregates or as coarser crystalline pods, intermixed with carbonate and chlorite.

Chlorite may be absent or may occur in amounts up to 20% as semi-continuous, foliated mats or seams, or as discrete clusters of anhedral grains, locally co-existing with actinolite. Sericite may be absent or may occur in amounts up to 30% as finely crystalline grains intermixed with quartz and ankerite or as foliated mats with chlorite. Albite, present in amounts less than 1%, occurs as discrete, subhedral, twinned porphyroblasts up to 0.3 mm in size. Actinolite and biotite occur as discrete, anhedral to subhedral porphyroblasts (less than 0.2 mm in size), often associated with patches of chlorite.

Structural Geology

The dominant structural feature on the property is a northeast-trending (040° to 070°), subvertically dipping, tectonic foliation. A second, less dominant trend, observed in the Centre Lake area, is north-northeast. The foliation, in general, is most intensely developed along the North Caribou River south of Centre Lake (North Caribou River Fault) and in the Centre Lake region. A strong linear fabric is present within the zone of intense foliation development, and is defined by the elongation of primary structures, such as quartz eyes or clasts in

conglomerate, or the intersection of foliation with bedding. The stretching and intersection lineations plunge vertically to steeply north-northeast, and, locally, steeply south-southwest (Figure 10). A north-trending crenulation cleavage and asymmetrically folded foliation are also common.

Medium scale, open to closed folds are developed locally in the clastic metasedimentary sequence and the iron formation units exposed south of Center Lake (Plate 2e). Plunges of the fold hinges are parallel to lineations observed in the same outcrop. These folds are accompanied by an axial planar foliation which is co-planar with the regional foliation.

The presence of several, discrete, northeast-trending faults, shown in Figure 10, is inferred from the apparent truncation of the north-trending lithological units. These inferred faults are in some cases coincident with quartz-Fe carbonate-chlorite schist zones developed in mafic volcanic rocks or with quartz-sericite-green mica schist zones developed in pelites and siltstones. The faults appear to be discontinuous to the northeast, and cannot be followed within mafic volcanic rocks.

Mineralization

Centre Lake: The quartz + Fe-Mg carbonate + chlorite + magnetite-bearing rock and cross-cutting quartz-sulphide veins exposed near the northeastern shore of Centre Lake contain highly erratic gold values up to 1065 ppb (Assessment Files Research Office, Ontario Geological Survey, Toronto). The distribution and the geometry of the veined and

sulphide-bearing zone are not known. The veins are typically less than 3 cm wide, occur in a stockwork fashion (Plate 2f), pinch out over distances of less than 1 m, and carry variable amounts of ankerite and up to 1% disseminated pyrite, chalcopyrite and arsenopyrite. Where quartz-rich, the carbonate-bearing wall rock carries up to 1% pyrite and arsenopyrite.

Other interesting gold values obtained from samples from the Centre Lake area include a value of 1275 ppb over a 0.5 m wide quartz-chlorite pod, containing 30% pyrite, associated with a 1 m wide iron formation unit (Assessment Files Research Office, Ontario Geological Survey, Toronto).

Diamond drilling in 1979 by St. Joseph Exploration Ltd. did not test the above mineralization, but three drill holes were collared in the immediate vicinity of Center Lake. The only significant gold values were obtained from a drill hole collared immediately northwest of Center Lake, and include 600 ppb from 1.53 m of chert containing 2% pyrite and traces of chalcopyrite and sphalerite.

North Caribou River Area: There are two locations along the south bank of the North Caribou River where significant gold values have been obtained. At the first location, due south of Center Lake, a grab sample from an outcrop of quartz- and sericite-altered quartz porphyry, containing disseminated pyrite, gave a value of 2870 ppb gold (Figure 10). A drill hole collared at this location by St. Joseph Exploration Ltd. intersected 1.5 m of quartz porphyry containing 5-10% pyrite-tourmaline veins and 350 ppb Au. At the second location, approximately 3 km northeast of the first, a 1 m wide, foliated, quartz-rich zone in

mafic volcanic rocks contains trace amounts of pyrite. A gold value of 2890 ppb over a 1 m width was obtained from this zone by Moss Resources Ltd. A drill hole collared at this location by St. Joseph Exploration Ltd. intersected 2.4 m of chert breccia with 60% pyrrhotite, 20% pyrite, traces of chalcopyrite, and 857 ppb gold; and a 1.5 m intersection of lean ironstone containing 1-2% pyrite/pyrrhotite and 2089 ppb gold.

NORTHERN DYNASTY EXPLORATION LIMITED (NORTH RIM PROPERTIES)

Location, Ownership and Development

A total of 115 claims in three claim blocks is held by Northern Dynasty Exploration Ltd. in trust for the Ontario Gold Joint Venture (Northern Dynasty Exploration Limited, Newfields Minerals Inc., Westfield Minerals Limited and Dunlop Exploration Ltd.). The three claim blocks, located north of Eyapamikama Lake (Figure 1; back pocket), are known as the Arseno Lake, Castor Lake and McGruer Lake Properties. They are collectively referred to as the North Rim Properties by Northern Dynasty Exploration Ltd. and in this report. The properties were initially staked in 1984 by Dunlop Exploration Ltd. under contract to the Ontario Gold Joint Venture.

There is no assessment work filed for the North Rim Properties previous to 1984, but there is evidence that limited trenching and diamond drilling were done prior to 1984 on the Castor Lake and McGruer Lake claims. During 1985, Dunlop Exploration Ltd. carried out geological mapping, ground magnetometer and EM surveys, prospecting, soil geochemistry surveys and a diamond drilling program (5 holes at McGruer Lake and 3 holes at Castor Lake, totalling 852 m).

Geology

Description of Lithologies

Mafic volcanic rocks: Mafic volcanic rocks are exposed in the northern portions of the North Rim Properties (Maps 1, 2 and 3; back

pocket). The flows are hornblende-rich and may be massive or intensely foliated, with pillows only present on and near the south shore of McGruer Lake (Map 1; back pocket). Amygdules and varioles have not been observed. Contacts between individual flows are only observed south of McGruer Lake, where narrow (less than 1 m wide), rusty weathered hornblende + grunerite + quartz + garnet-rich units, interpreted to be Fe-rich clastic sediments, are exposed between flows. Near flow contacts, pillows are typically small (less than 0.25 m), bleached, and locally brecciated. In the interiors of some massive flows, irregular, bleached, quartz-rich segregations or zones may occur. Near the contact of the flows with the main sedimentary sequence, alternating, bleached (quartz-rich) and dark (hornblende-rich), centimetre scale banding may be present.

Ultramafic rocks: One serpentine-bearing outcrop, interpreted to be ultramafic in origin, is present south of McGruer Lake, immediately north of the major volcanic-sedimentary contact (Map 1; back pocket). Examination of a thin section and X-ray diffraction analyses have shown that this rock consists of serpentine and talc pseudomorphs, after olivine and pyroxene, within a groundmass of locally massive orthopyroxene, dolomite, magnesite and talc. The carbonate occurs as blebs up to 0.25 cm in size, intermixed with lesser orthopyroxene and talc, and typically weathers a rusty colour.

Intermediate to felsic volcanic rocks: Massive, monolithic to heterolithic, pyroclastic breccia units of andesite to rhyolite composition occur intercalated with mafic flows south of McGruer Lake (Map 1; back pocket) and east of Pollux Lake (Map 2; back pocket).

These units, which are locally intensely foliated, are typically lensoid, less than 150 m thick, and are easily distinguishable in outcrop from the mafic volcanic rocks by their bleached appearance and their quartz and plagioclase-rich mineralogy.

Fragments, which comprise less than 20% of the breccias, are elongate and range in size from several millimetres to several centimetres (Plate 3a). The fragments in the heterolithic varieties consist of roughly equal proportions of basalt (hornblende-rich) and andesite/dacite (quartz-plagioclase-sericite-rich), with rare, fine grained rhyolite (quartz-rich) fragments. Within monolithic breccias, the fragments are dominantly felsic in composition. The groundmass of all the breccias is composed dominantly of quartz + sericite + biotite + plagioclase. Quartz eyes (1%) and plagioclase porphyroblasts occur in both the groundmass and the intermediate/felsic fragments.

Up to 5% disseminated arsenopyrite and pyrite occur within rusty weathered portions of a rhyolite unit exposed east of Pollux Lake (Map 2; back pocket). These sulphides occur within zones of pervasive quartz replacement of the rhyolite; the structural control of these replacement zones is unknown. South of Pollux Lake, a continuous, 1 to 3 m thick unit of locally brecciated, cherty rhyolite to dacite occurs within a sequence of quartz-biotite-garnet schist and can be used as a stratigraphic marker unit at this location.

Chemical metasediments: Several east-trending, semi-continuous ironstone units occur on the North Rim Properties near the major sedimentary-volcanic contact (Maps 1, 2 and 3; back pocket). These

include well-banded chert-magnetite and chert-magnetite-grunerite iron formations, and vaguely banded chert-magnetite-grunerite iron formation.

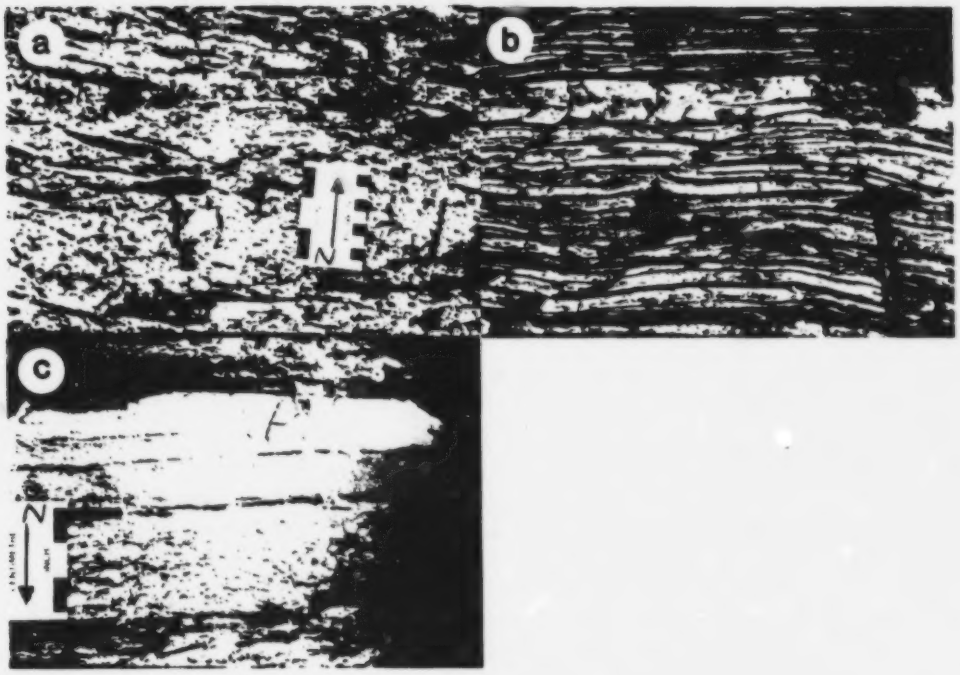

Plate 3. Lithologies in the McGruer and Castor Lakes area.

(a) Outcrop, located south of McGruer Lake, of felsic heterolithic pyroclastic breccia showing flattened mafic fragments and quartz-rich fragments. (b) Outcrop of well banded chert-grunerite BIF, located near the south shore of Castor Lake. (c) Outcrop, located south of McGruer Lake, showing well developed graded beds, indicating a south facing direction.

At McGruer Lake, three distinct units of iron formation are present. The most extensive consists of weakly banded, rusty weathered, chert-magnetite-grunerite units up to 2 m thick, intercalated with quartz-biotite-staurolite-chlorite-garnet schist and garnet-free, well-bedded pelite - siltstone units to form an approximately 50 m wide sequence (Map 1; back pocket). This sequence is flanked to the north by

mafic volcanics and to the south by a quartz-biotite-sericite-garnet schist and a pelite - siltstone - polymictic conglomerate sequence. The iron formation consists of 50 to 95% quartz, 5 to 30% grunerite, 5 to 20% magnetite and variable, minor amounts of garnet, biotite, chloritoid, staurolite, andalusite and chlorite. Quartz-arsenopyrite veins and discontinuous (less than 1 m in size), rusty weathering pods of disseminated arsenopyrite and pyrrhotite are common in the weakly banded chert-magnetite-grunerite iron formation units that are intercalated with the garnetiferous schists.

The second unit of iron formation occurs as a lens-shaped body up to 20 m wide, located southwest of McGruer Lake, within the sequence of quartz-biotite-sericite-garnet schist and pelite - siltstone. It consists of well-banded chert, grunerite and magnetite, with distinct, 10 to 15 cm wide, darker, grunerite-rich units that contain up to 20% spheroidal to ellipsoidal, quartz-rich structures up to 1 cm in diameter.

The third unit of iron formation occurs as a narrow (up to 5 cm wide) lens near the southwestern shore of McGruer Lake, within the quartz-biotite-sericite-garnet schist. It consists of well-banded chert and magnetite showing random intraformational fold structures, interpreted to be pre-lithification, soft sediment folds.

A relatively continuous unit of iron formation is exposed along and near the southern shores of Castor and Pollux Lakes (Map 2; back pocket). This unit is dominantly banded chert and grunerite (Plate 3b) and is variable in thickness, attaining widths up to 40 m near the western shore of Castor Lake, and thinning to 1 m south of Pollux Lake.

Intercalated pelitic units are locally common, especially near Pollux Lake. The iron formation is in contact to the south with quartz-biotite-sericite-garnet schist, and, to the north, with quartz-biotite-sericite-garnet schists and fine grained, well-bedded siliciclastic sediments.

The grunerite-rich bands contain lesser amounts of quartz, magnetite and garnet. Grunerite and garnet (1 mm in diameter) also occur in transposed, millimetre-scale bands and in fractures cutting the chert-grunerite banding in the Castor Lake region.

The pelitic units consist of variable amounts of chlorite, sericite, biotite, quartz, garnet and staurolite.

Several other narrow, discontinuous, chert and chert-grunerite units, similar to those described above, occur in the southwest Castor Lake region.

Near the western shore of Castor Lake, a 3 to 4 m wide quartz and sulphide-rich unit (Castor Lake gold showing) is intermittently exposed for 100 m within garnet-biotite schist. Although this unit contains little magnetite or grunerite, it is stratigraphically equivalent to a banded chert-grunerite iron formation unit intersected by diamond drilling near the western shore of Castor Lake and is interpreted to be a quartz-sulphide replacement zone within this iron formation, as described below.

Other sulphide-rich zones within iron formation occur as isolated, rusty weathering pods (up to 1 m in size) containing 1 to 10% disseminated pyrrhotite and arsenopyrite in the eastern Pollux Lake region, and as 1 to 10 cm wide zones of massive, medium grained,

crystalline pyrite along the northern contact of iron formation south of Castor Lake.

In the Arseno Lake region, a unit of iron formation is intermittently exposed over a strike length of approximately 3.5 km (Map 3; back pocket). This unit is up to 5 m wide and consists dominantly of poorly to well-banded chert-grunerite and intercalated quartzite. It is flanked to the north by garnet-biotite schist, and to the south, by a sequence of schist and pelite-siltstone-arenite. Quartz-sulphide-bearing gossan zones (Arseno Lake gold showing) up to 1 m wide, described below, occur at several locations along the northern contact of the iron formation.

Clastic metasediments: Clastic sediments are exposed in the southern portions of the North Rim Properties. The most voluminous lithologies are thinly interbedded pelite and siltstone (Maps 1, 2 and 3; back pocket). To the north, graded units comprising basal, coarse grained, quartz wacke lag deposits (Plate 3c), and thin (less than 25 cm wide) interbeds of quartz wacke, quartz arenite and chert are common. In the McGruer Lake area, a lens up to 50 m wide of massive, medium to coarse grained, quartz wacke to quartz arenite is well exposed within the pelite-siltstone sequence. This lithology, which weathers rusty, typically consists of 90% quartz eyes in a matrix consisting of variable amounts of hornblende, sericite, biotite, andalusite and garnet.

Units of quartz-biotite-garnet schist occur intercalated with pelite and siltstone beds and iron formation near the major volcanic-sedimentary contact (Maps 1, 2, and 3; back pocket). The schist contains up to 40% garnet grains, which occur as isolated euhedral

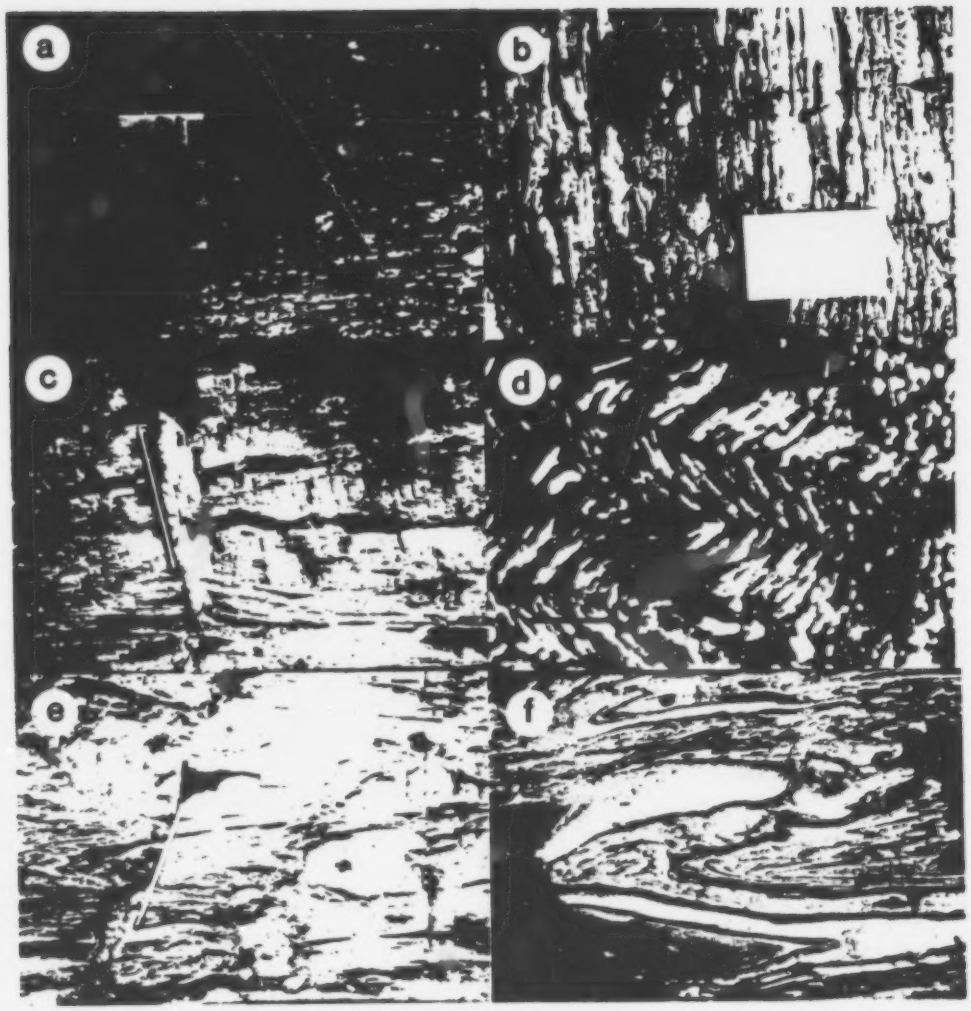

Plate 4. Lithologies in the McGruer - Castor - Arseno Lakes area.

(a) Outcrop of garnet-biotite schist, located south of McGruer Lake, showing 30% subhedral garnet porphyroblasts. (b) Outcrop of "ribbed" garnet-biotite-sericite schist, located south of McGruer Lake. (c) Outcrop showing an extensional quartz vein and fractures in foliated siltstones located south of McGruer Lake. (d) Photomicrograph of kink bands in biotite-chlorite schist, defined by reoriented biotite and chlorite. Sample is from the Arseno Lake area. Scale bar = 0.2 mm (crossed nicols). (e) Outcrop showing medium scale, closed folds in pelite-siltstone interbeds near the McGruer Lake gold showing. (f) Outcrop showing medium scale, closed folds in hornblende-rich pelite/ siltstone interbeds located southeast of the Castor Lake gold showing.

porphyroblasts to 1 cm in diameter or as grain aggregates aligned or elongate parallel to foliation (Plate 4a). The schist also contains accessory staurolite, andalusite, grunerite, hornblende, sericite, chlorite, chloritoid and opaques (pyrite, ilmenite, magnetite). The garnets are most abundant within biotite-rich zones of the schist. They occur locally as irregular, interconnecting, resistant ribs or as "fish hook" structures (Plate 4b). In other areas of the schist, delicate, millimetre-scale sedimentary laminations are locally preserved. Both garnet-free and garnet-rich laminae are present, suggesting a primary, bulk composition control for these garnet-rich lithologies. The protolith of the garnet-bearing schist is therefore interpreted to be an Fe-rich clastic sediment, because of its close spatial association with well-bedded pelites, siltstones and iron formation.

A distinctive, 20 m wide, rusty weathered, schistose unit is present in the Castor Lake region (Unit 4e, Map 2; back pocket). This rock contains a mineral assemblage of quartz + sericite + staurolite + chlorite + andalusite. Primary sedimentary bedding was not observed, but the unit is interpreted to be sedimentary in origin because of the relative abundance of quartz and aluminous minerals.

Several units of polymictic conglomerate occur on the North Rim Properties. In most locations, clasts are moderately flattened. At McGruer Lake, a lens of conglomerate and chlorite schist, up to 50 m thick, occurs within the sequence of schist, pelite and siltstone (Map 1; back pocket). This conglomerate consists of up to 15% subrounded, intermediate to felsic, quartz porphyry clasts up to 15 cm in size, and 5% mafic clasts to 10 cm in size, within a matrix rich in quartz and

hornblende. Narrow, pelite-siltstone units up to 1 m thick are locally intercalated with the conglomerate. Garnets were not observed in these rocks.

In the Arseno Lake region, a polymictic conglomerate unit up to 350 m thick, similar to that at McGruer Lake, is intermittently exposed in the southern portion of the property. This conglomerate is in contact to the north with a pelite-siltstone-arenite-iron formation sequence, and to the south, with mafic volcanics (Map 3; back pocket). It consists of approximately 60 to 70% foliated amphibolite, lacking clasts, and 30 to 40% foliated amphibolite, containing up to 30% clasts. The clasts consist dominantly of fine-grained, intermediate to felsic volcanic rocks with rare quartz eyes, angular clasts of bedded chert, and rare clasts of mafic volcanic rocks. Up to 30% quartz clasts may also be present but these are interpreted to be tectonically brecciated quartz veins. Intercalated pelites, siltstones and arenites, garnets, and primary sedimentary features are all absent from this unit.

A second unit of polymictic conglomerate occurs intercalated with pelitic sediments in the southeastern portion of the Arseno Lake Property. This unit is poorly exposed and is characterized by 10 to 20% rounded, cobble-size clasts of both granitic and felsic volcanic affinity.

Structural Geology and Metamorphism

The paucity of outcrop and the lack of facing indicators have made an interpretation of the structural geology along the North Rim difficult. The graded beds within the clastic sediments near McGruer

Lake, and pillows within mafic volcanics west of Arseno Lake and at McGruer Lake, indicate that the sequence of rocks faces south. Satterly (1941) also describes south-facing pillows in the area east of McGruer Lake.

All of the rocks show varying degrees of deformation and metamorphic recrystallization, described below, but primary lithologies can be identified in most locations. The major volcanic-sedimentary contact is the focus of relatively intense deformation over a width of 200 to 400 m, but no discordant relationships of lithological units (*i.e.* evidence for a fault) were observed across this zone, which is interpreted as a shear zone. The focus of deformation along this contact is interpreted to be a function of the relatively high ductility contrast between the different lithological units.

The northern portion of the sedimentary sequence and all of the mafic volcanics to the north have been metamorphosed to lower amphibolite facies conditions, characterized by mineral assemblages of hornblende + plagioclase in the mafic volcanic rocks and quartz + biotite + staurolite + sericite + hornblende + chlorite + magnetite + cordierite + andalusite + chloritoid in the clastic sediments. To the south, the clastic sediments contain an assemblage of quartz + sericite + biotite + chlorite, and are interpreted to be of upper greenschist facies. The first appearance of garnet in the sediments defines the garnet isograd shown on Maps 1, 2 and 3 (back pocket); this isograd is approximately parallel to the volcanic-sedimentary and granite-greenstone contacts. These metamorphic conditions are unchanged along the 30 km strike length of the North Rim.

In the following section, a detailed description of the structural elements, particularly within the shear zone along the contact region, is presented in order to provide a framework for describing the gold occurrences in this same region. The metamorphic petrography is also described, in order to document the relationship of deformation to metamorphism and to show whether the mineral assemblages represent original bulk compositions of protoliths, or result from hydrothermally altered rock compositions.

Foliation and lineation: The most prominent structural feature in the North Rim Properties is a 085°- to 110°-trending, vertically dipping, planar fabric defined by a pronounced foliation or the dimensional orientation of primary features, such as volcanic pillows, clasts in conglomerates, and fragments within pyroclastic breccias. In most places this fabric is parallel to the strike and dip of lithological units, but in some instances up to a 20° difference can be observed between the strikes of foliation and bedding, which strikes dominantly at 090°. The planar fabric is best developed within the 200 to 400 m wide shear zone, which is coincident with lithologically complex regions along the major sedimentary-volcanic contact, and along zones of unknown width and strike length within mafic volcanics to the north. Foliation within these zones is parallel to their boundaries. Intervening domains of rock show relatively weak foliation development.

Within mafic volcanic rocks, foliation is defined by parallel orientation of amphiboles (hornblende) and, locally, by aggregates of quartz and plagioclase. Later, superimposed structures (*i.e.* kink banding, crenulation cleavages) are absent, although the foliation is

often of an anastomosing, sinusoidal nature. Prismatic amphiboles locally show a strong preferred dimensional orientation along foliation surfaces and generally plunge moderately to the east, but this linear fabric could not be identified in the more extensive, finer grained, foliated volcanics. Quartz veining and carbonate alteration were not observed within these foliated zones.

Along the volcanic-sedimentary contact, flattened, primary structures with no obvious linear orientation are common. Foliation in this region is defined by the parallel orientation of amphiboles in mafic volcanic rocks and of biotite, sericite, and chlorite in clastic sediments. Planar and linear penetrative fabrics are poorly developed within ironstones because of their relatively competent nature. Hornblende-rich interbeds (dikes/sills?) which are concordant with the sedimentary sequence and foliation are typically boudinaged and often contain fibrous growths of tremolite or quartz at the boudin necks. Quartz-tourmaline-pyrrhotite veins of unknown geometry are similarly boudinaged and may show various degrees of rotation.

Two fabrics which pre-date the dominant regional foliation are locally observed on the North Rim Properties. One is a penetrative fabric in pelitic interbeds in the McGruer - Castor - Pollux Lakes region: this fabric is crenulated by the regional foliation and is parallel or slightly oblique to bedding. The second fabric is a northwest-trending, spaced cleavage, observed in arenaceous interbeds near McGruer Lake: in most cases, this fabric is deformed into steep, west-plunging, kink folds by the regional foliation.

In addition, two planar fabrics which are contemporaneous with or post-date the regional foliation are observed. One is a 350°- to 010°-trending set of extension fractures common in all lithologies near McGruer Lake, and less common at Castor and Pollux Lakes. These fractures may be filled by gash-like, extensional quartz veins (Plate 4c). The other late fabric is a 120°- to 140°-trending, penetrative crenulation foliation which occurs rarely in the clastic sediments in the southern Arseno Lake region (Map 3, back pocket and Plate 4d).

Folds: The paucity of outcrop and the lack of facing indicators have made the identification of regional folds on the properties difficult. The sequence of rocks is, however, interpreted to face south (see above).

Near the volcanic-sedimentary contact, medium scale (1 m to 10 m amplitude), closed folds are locally present in the clastic and chemical sediments, especially in the vicinity of the Castor and McGruer Lakes gold occurrences (Plate 4e, f). The folds plunge moderately (45° to 60°) to the east or west and have vertical axial surfaces which are parallel to the regional foliation. These folds are interpreted to be related to larger scale (greater than 10 m amplitude), disharmonic, asymmetric folds which typically show truncated limbs (Maps 1 and 2; back pocket).

In addition to the above fold styles, intrafolial folds are common within individual units of iron formation. These do not appear to be related to the disharmonic folds. They are typically asymmetric, plunge moderately east or west, have rootless limbs and show evidence of refolding.

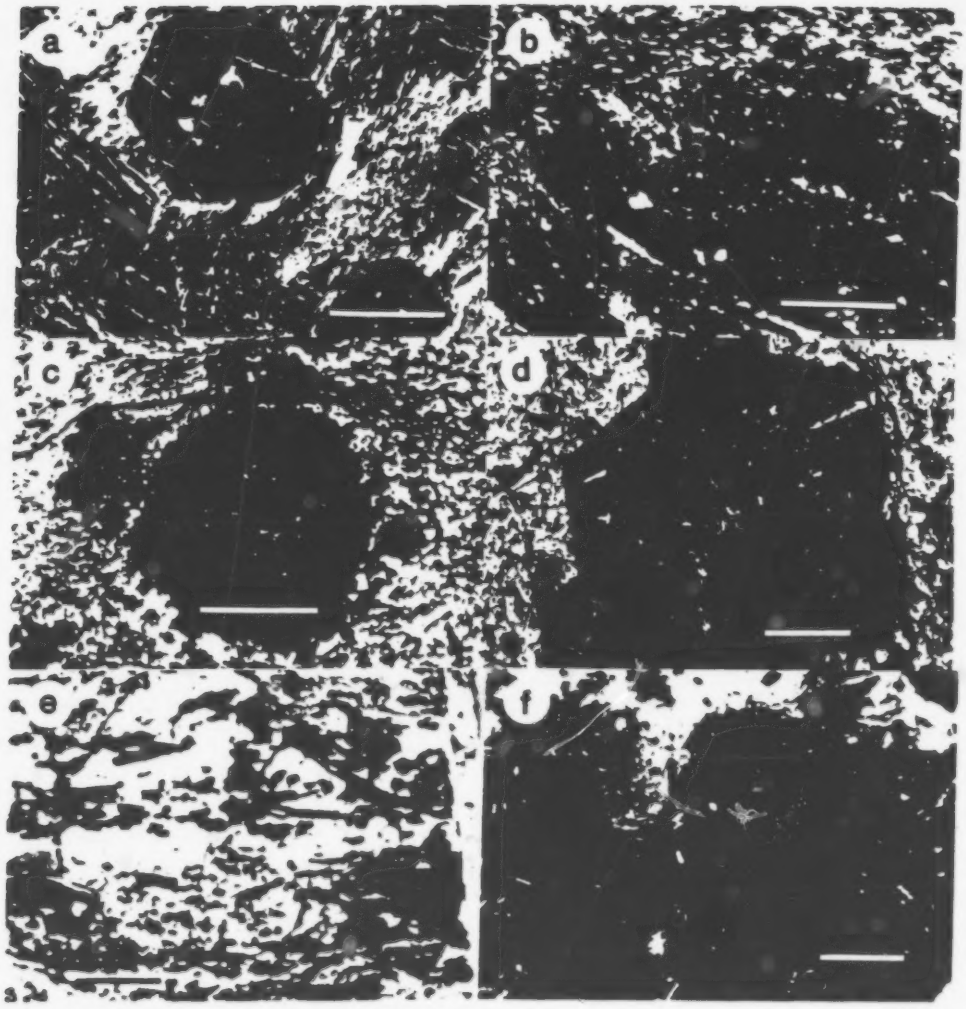

Plate 5. Photomicrographs of garnet porphyroblasts in lithologies from the McGruer and Castor Lakes areas.

(a) Post-kinematic porphyroblasts with cores rich in quartz inclusions in a groundmass of foliated chlorite. The porphyroblasts are cross-cut by extensional quartz veins. Sample is from the McGruer Lake area. Scale bar = 1.0 mm (crossed nicols). (b) Post-kinematic porphyroblast, showing inclusion trails of quartz, in a groundmass of quartz, biotite and chlorite. Sample is from the Castor Lake area. Scale bar = 1.0 mm (crossed nicols). (c) Post-kinematic porphyroblast, with a chlorite-rich core, in a groundmass of weakly foliated quartz, biotite and chlorite. Sample is from the Castor Lake area. Scale bar = 1.0 mm (crossed nicols). (d) Porphyroblast with a core rich in fibrous grunerite inclusions, in a groundmass of grunerite. Sample is from the

Metamorphic petrology: One garnet type can be identified within the sedimentary sequence by its relationship with the regional foliation (Plate 5). It occurs predominantly as poikiloblastic, subhedral to anhedral porphyroblasts to 0.5 cm in size and often as ragged, elongate grains parallel to foliation. Most of the garnets have cores rich in inclusions of quartz, chlorite and grunerite, or display inclusion trails of quartz or biotite which parallel the foliation in the groundmass (Plate 5a to e). Some of the garnets present in the schists adjacent to iron formation units have cores rich in fibrous grunerite and magnetite (Plate 5f).

Garnets are widespread, but are most abundant within quartz-biotite-garnet-staurolite schists adjacent to the units of iron formation. The garnets are interpreted to be syn- to post-tectonic, and often exhibit an extension fracture set perpendicular to foliation, which may be locally filled with quartz and chlorite (Plate 5a). Staurolite is also relatively abundant, in amounts up to 10%, within the amphibolite grade sediments and generally occurs as isolated, subhedral to anhedral porphyroblasts to 0.1 mm size. These porphyroblasts locally contain quartz-rich inclusion trails, parallel to foliation in the groundmass (Plate 6a). Andalusite occurs as subhedral porphyroblasts in amounts up to 5%, intimately associated with staurolite. These porphyroblasts also may be locally inclusion-rich (Plate 6b). Blue-

McGruer Lake area. Scale bar = 0.2 mm (crossed nicols). (e) Post-kinematic garnet showing biotite inclusion trails. Sample is from the McGruer Lake area. Scale bar = 0.2 mm (plane light). (f) Porphyroblasts showing magnetite (opaque) and fibrous grunerite inclusions. Sample is from the McGruer Lake area. Scale bar = 0.2 mm (crossed nicols).

green amphiboles occur as isolated, subhedral porphyroblasts or as fibrous mats (actinolite) intermixed with quartz + biotite + garnet assemblages.

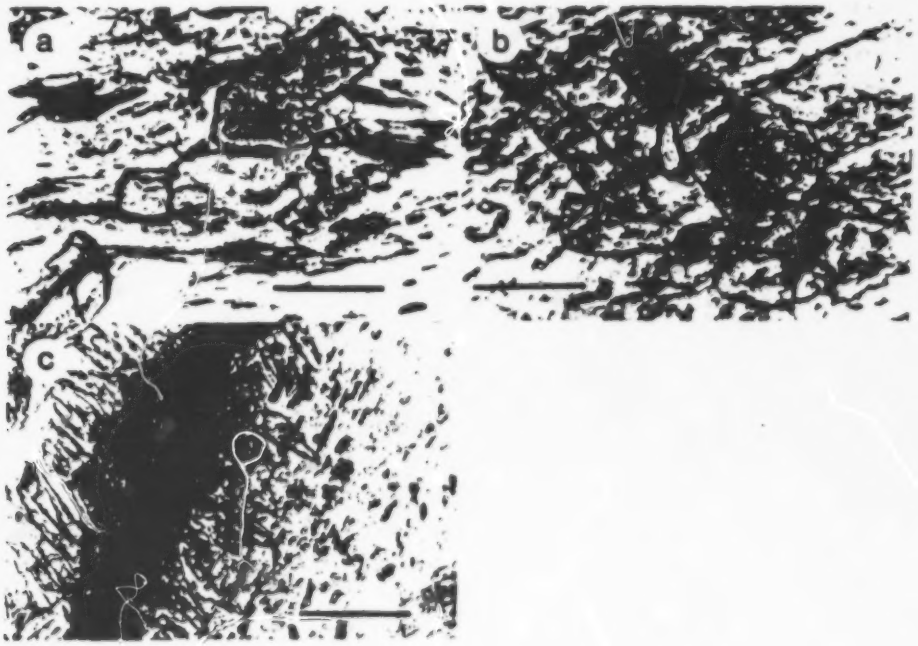

Plate 6. Photomicrographs of metamorphic minerals in lithologies from the McGruer Lake area.

(a) Post-kinematic subhedral staurolite porphyroblasts with inclusion trails of opaque residua. Scale bar = 0.15 mm (plane light). (b) Post-kinematic subhedral andalusite porphyroblasts with inclusion trails of opaque residua. Scale bar = 0.15 mm (plane light). (c) Radiating prismatic, colourless amphibole (tremolite) porphyroblasts overgrowing a hornblende porphyroblast and foliation. Scale bar = 0.15 mm (plane light).

Mineralization and Alteration

McGruer Lake: Five of 28 rock samples collected in this study from the McGruer Lake Property and analyzed for gold, yielded values of

from a sulphide mineralized zone hosting the McGruer Lake Showing (Bartlett *et al*. 1985), which was diamond drilled in 1985 by Northern Dynasty Exploration Limited.

The gold mineralization is located within the shear zone along the volcanic-sedimentary contact described above, and is hosted by chert-grunerite-magnetite iron formation and quartz-biotite-sericite-garnet-chlorite-staurolite schist. The mineralization consists of local (less than 1%), narrow (less than 10 cm), discontinuous, quartz-arsenopyrite veins trending parallel or subparallel to foliation, and sulphide-rich pods (less than 1 m in size) containing massive to disseminated arsenopyrite and pyrrhotite, elongate parallel or subparallel to foliation. All of the quartz-sulphide pods and veins occur within individual units of iron formation (less than 1.5 m wide) or within the schist immediately adjacent to the iron formation. In foliated portions of the iron formation and the schist, sulphide mineralization may also occur as seams along foliation surfaces. The sulphide-rich zone is up to 5 m wide, but the sulphides are not pervasive throughout this zone, nor is there a direct relationship between high sulphide content and high gold values. The best gold value from the zone is 4.5 g/ton across a width of 0.7 m, obtained from chip sampling by Northern Dynasty Exploration Limited (Assessment Files Research Office, Ontario Geological Survey, Toronto).

Mineralized pods and veins on the McGruer Lake Property can be traced intermittently along strike for approximately 100 m, but the distribution and continuity of the mineralization at depth are unknown. Detailed mapping in the vicinity of the showing indicates that the

Detailed mapping in the vicinity of the showing indicates that the lithological units have a predominant west plunge and that mineralization is restricted to the north limb (near the crest) of an highly attenuated, west-plunging isoclinal antiform (Map 1; back pocket). Six diamond drill holes to test the strike and depth continuity of the mineralized zone intersected the iron formation, but returned no significant gold values (Figures 11 and 12, and Assessment Files Research Office, Ontario Geological Survey, Toronto).

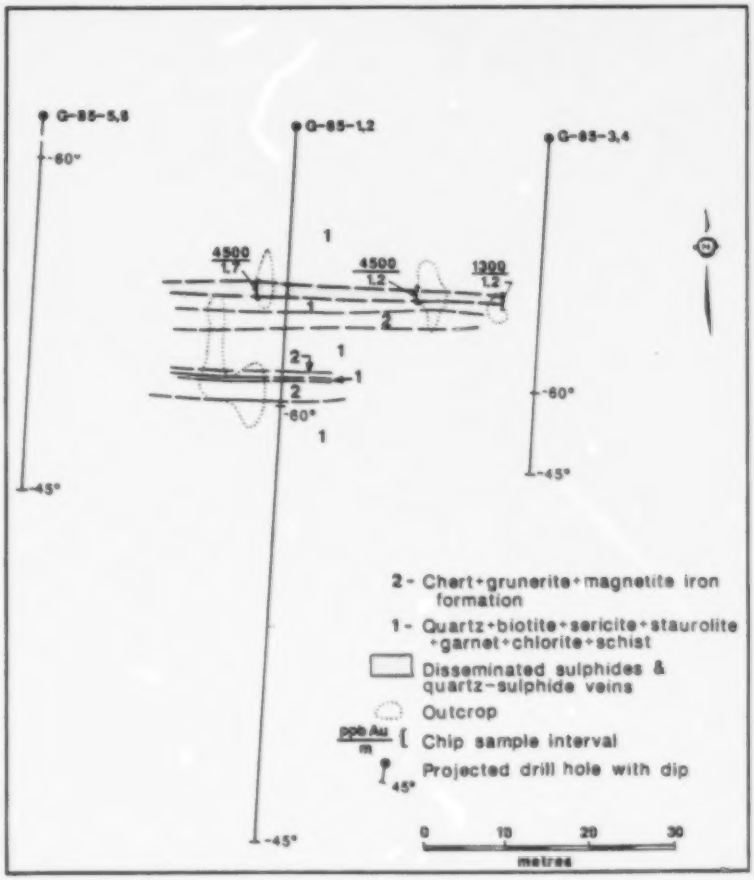

Figure 11. Geology and drill hole locations at the McGruer Lake gold showing area.

There is no visible alteration halo surrounding the mineralized veins or pods. Rusty weathering of the iron formation units is a widespread feature, reflecting the oxidation of grunerite, magnetite and sulphides, and is therefore difficult to use as a direct exploration tool. Petrographically, it is difficult to determine the presence of alteration beyond the tight structures hosting the quartz veins and pods. Garnet + grunerite + staurolite + andalusite + biotite assemblages adjacent to the mineralized zone are interpreted to represent the primary bulk composition of the rock and do not reflect replacement phenomena or a spatial relationship to mineralization. Chlorite was not observed as a replacement product but occurs rarely in fractures in garnet porphyroblasts, intergrown with biotite, and locally as a major component of the groundmass, co-existing with garnet. Amphibole, interpreted to be tremolite (colorless in thin section), was observed in one sample to overgrow and radiate outwards from anhedral hornblende porphyroblasts (Plate 6c).

South of the mineralized zone, a unit of quartz-sericite schist, interpreted to be igneous in origin (quartz porphyry), is characterized by an absence of primary feldspar, abundant sericite and biotite, and locally abundant quartz-tourmaline veins and euhedral tourmaline along foliation planes. The veins and the mineral assemblage are indicative of hydrothermal alteration but negligible gold values were obtained from the veins and the wallrock. This unit was observed to be concordant and in sharp tectonic contact with relatively undeformed and unaltered pelite-siltstone sequences, suggesting that it may be a fault slice.

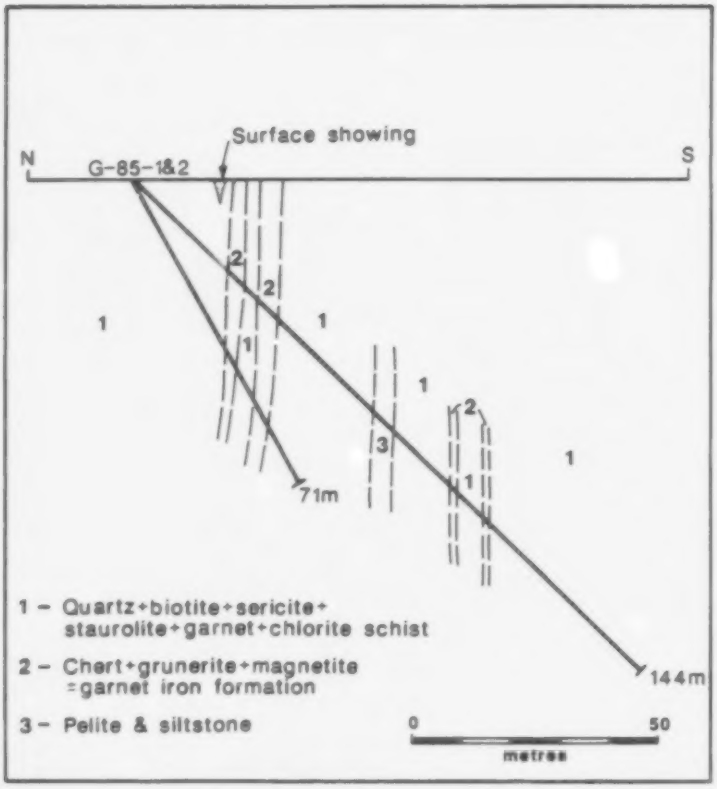

Figure 12. Drill hole cross-section through the McGruer Lake gold showing.

Castor Lake: Two of the 31 rock samples collected from the Castor Lake Property and analyzed for gold yielded values of greater than 1000 ppb (Map 2; back pocket). These two samples are from a mineralized zone, the Castor Lake Showing (Assessment Files Research Office, Ontario Geological Survey, Toronto), which was diamond drilled in 1985 by Northern Dynasty Exploration Limited. The highest gold value obtained from this zone by Northern Dynasty Exploration Limited is 1.95 ppm over 1.9 m.

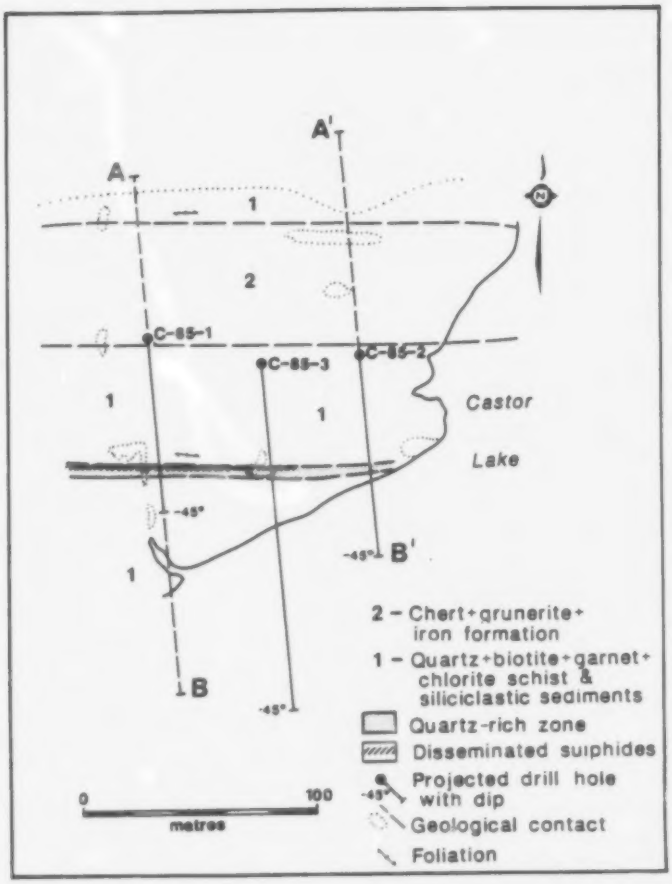

Figure 13. Geology and drill hole locations at the Castor Lake gold showing area.

The Castor Lake Showing is hosted by an east-trending, vertically dipping, quartz-rich unit located within the shear zone along the volcanic-sedimentary contact, flanked to the north and south by quartz-biotite-sericite-chlorite-garnet schist. Detailed mapping and diamond drilling indicate that the mineralized unit is stratigraphically equivalent to chert-grunerite iron formation (Figures 13, 14 and 15), but contact relationships between the quartz-rich unit and the iron

formation have not been observed. The mineralized unit is well exposed at three locations along a strike length of 90 m. The plunge of the mineralization is unknown. The amount of sulphides and the gold values are highest within the northern section of the unit, which is thickest (2.0 m) at the eastern exposure and thinnest (1.0 m) at the west, with sulphide contents ranging from 1 to 15%. The dominant sulphide is arsenopyrite, which occurs as subhedral to euhedral crystals disseminated throughout the quartz and as millimetre-scale seams parallel with the regional foliation. Lesser amounts (1%) of pyrrhotite occur intermixed with the arsenopyrite, and in stringers within the adjacent schist, parallel with the foliation.

There is no recognizable alteration halo within the schists surrounding the mineralized zone, but several features are unique to the schists in the immediate area of the mineralization. Within the schist on the immediate north side of the mineralized zone, up to 5% coarsely crystalline (up to 1 cm in diameter), subhedral, poikiloblastic garnets occur, interpreted to be syn-kinematic in origin (Plate 7). These garnets have a close spatial relationship with several narrow (less than 25 cm wide), discontinuous, quartz-tourmaline-pyrrhotite veins. The orientation of the veins is unknown, but on the horizontal surface of the outcrop, they are subparallel to foliation and are typically boudinaged and rotated in a right-handed sense. The foliation in the schist is locally "snowballed" around garnet porphyroblasts, also in a right-handed sense. On the south side of the mineralized zone, a 20 cm wide quartz + tremolite-actinolite + calcite vein is exposed, but quartz-tourmaline veins and coarse-grained garnet were not observed.

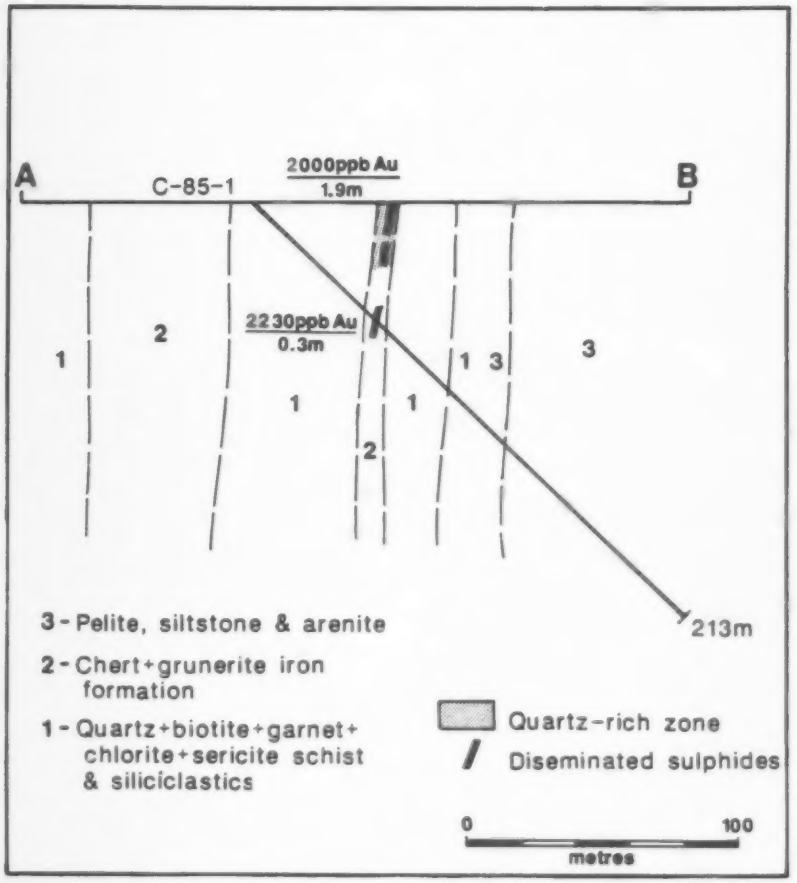

Figure 14. Drill hole cross-section A - B; Castor Lake gold showing.

Arseno Lake: Two of 9 rock samples collected from the Arseno Lake Property and analyzed for gold yielded values of greater than 1000 ppb (Map 3; back pocket). The samples are from two distinct, sulphide-mineralized zones located within the shear zone along the volcanic-sedimentary contact.

The first sulphide zone, located in the western portion of the map area (Map 3; back pocket), is hosted by a quartz-biotite-garnet schist

which is flanked to the north by mafic volcanics and, to the south, by chert-grunerite-magnetite iron formation. The sulphides, which occur

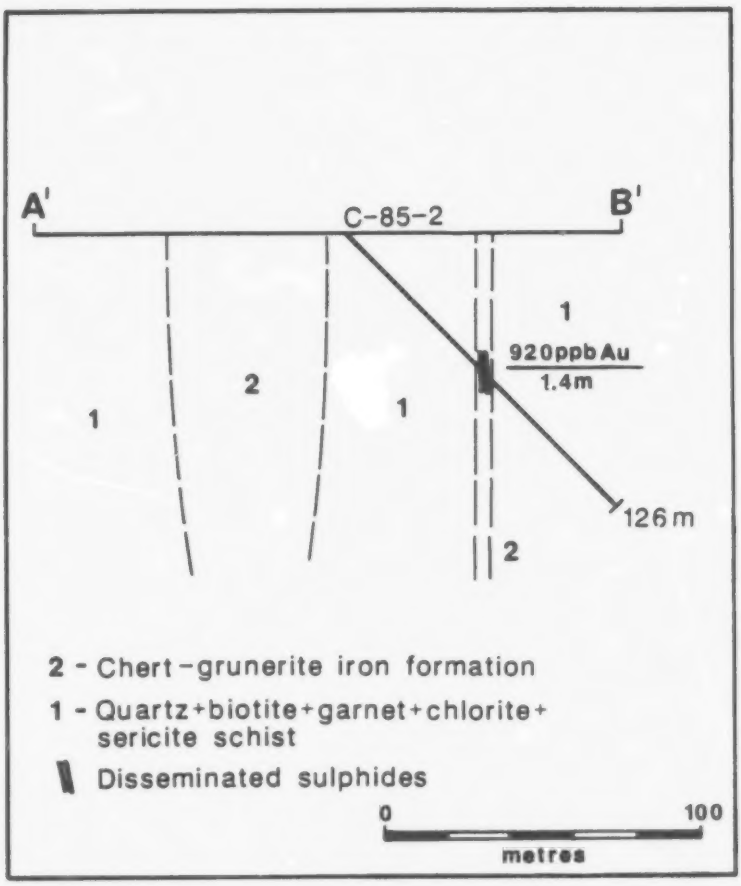

Figure 15. Drill hole cross-section A' - B'; Castor Lake gold showing.

within a small lens (1.5 m by 30 cm) exposed in a single outcrop, are variable in content, ranging from 1% to 10%, and include, in order of decreasing abundance, sphalerite, galena, pyrite and chalcopyrite. High silver values (11,175 g/ton (32.6 oz/ton) and 295 g/ton (8.6 oz/ton))

are associated with the sulphides, but it is not known whether the silver occurs as a sulphide mineral or in its native state. High gold values (2400 ppb and 790 ppb) are associated with high sulphide content and the high silver values (Map 3; back pocket). Arsenopyrite and pyrrhotite were not observed and arsenic values from the two samples taken from this zone are below 200 ppm.

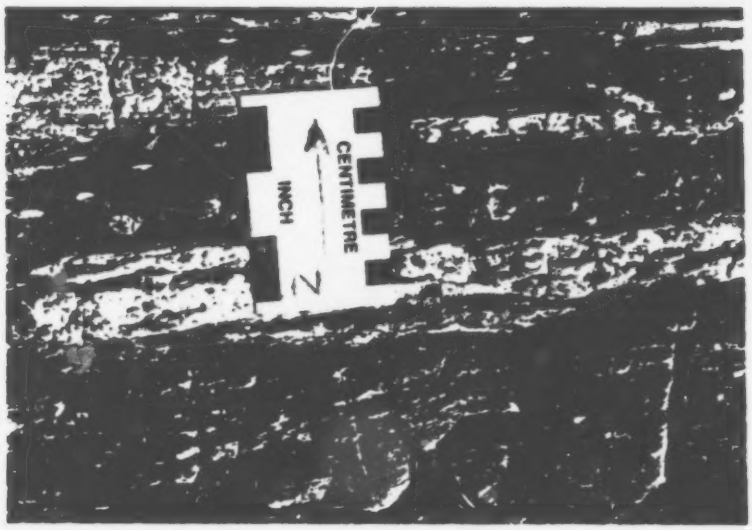

Plate 7. Outcrop showing coarsely crystalline garnet porphyroblasts in garnet-biotite schist adjacent to a quartz vein near the Castor Lake gold showing.

Sphalerite, present in amounts up to 10%, is typically brown, fine to medium crystalline, and occurs intermixed with galena, chalcopyrite and pyrite, either as blebs within the quartz-rich wall rock or concentrated along foliation planes in relatively biotite-rich portions. Galena is present in amounts up to 5% as medium crystalline blebs intermixed with sphalerite and chalcopyrite and as local, isolated, euhedral crystals concentrated along foliation planes. Chalcopyrite is

present in amounts less than 1%, intermixed with sphalerite, galena and pyrite.

The second zone, located 2.5 km east of the first occurrence, is poorly exposed at two locations (Map 3; back pocket), indicating a probable east-west strike length of 600 m. The mineralization consists of a 1.1 m wide, quartz-sulphide replacement zone and heavily oxidized wall rock along the contact between chert-grunerite iron formation and garnet-biotite schist. The sulphides, which include sphalerite, galena, chalcopyrite and pyrite, occur locally disseminated and as massive to semi-massive pods within quartz. The barren quartz does not contain sulphides but a 1.0 m chip sample across the zone, containing an estimated 15% sulphide content, yielded a gold value of 1370 ppb.

SULPETRO MINERALS LIMITED
(TEAL PROPERTY)

Location, Ownership and Development

The Teal Property is located 630 m east of Agutua Arm of Weagamow Lake and 900 m north of Randall Lake (Figure 1; back pocket). The main showing was discovered in 1957 when the property was trenched and diamond drilled. The pre-1971 exploration and development history of the prospect is summarized by Thurston *et al.* (1979). The property was held in 1986 by Sulpetro Minerals Ltd. which carried out 1:2400 scale mapping and diamond drilling (3 holes) in 1979. In 1986, geological mapping, stripping and lithogeochemical sampling were carried out by the Ontario Geological Survey (Piroshco and Shields 1985).

Geology

Description of Lithologies

Mafic volcanics: Mafic volcanic rocks (Figure 16) have been mapped in the southern portion of the property. These are massive flows, which are dominantly composed of actinolite and chlorite.

Chlorite-calcite schist: A unit of chlorite- and calcite-rich rock occupies the central portion of the map area (Figure 16). This rock is typically beige on a weathered surface and locally is highly schistose. In several outcrops near West Lake, up to 10%, bleached and elongate clasts up to 5 cm in length are present within both foliated

and massive portions of this rock type; these are interpreted to be pyroclastic in origin (Plate 8a).

The leucocratic appearance of this rock is due to its content of calcite (up to 20%); fine grained, polycrystalline quartz (up to 25%), and sericite (minor amounts). The calcite occurs as veinlets parallel to foliation and disseminated in the groundmass. Other minerals in the rock include actinolite (up to 20%), which occurs as boudinaged, subhedral porphyroblasts within discrete laminae; chlorite (up to 40%), which occurs as fibrous aggregates in the groundmass, and variable amounts of epidote, biotite and opaque minerals.

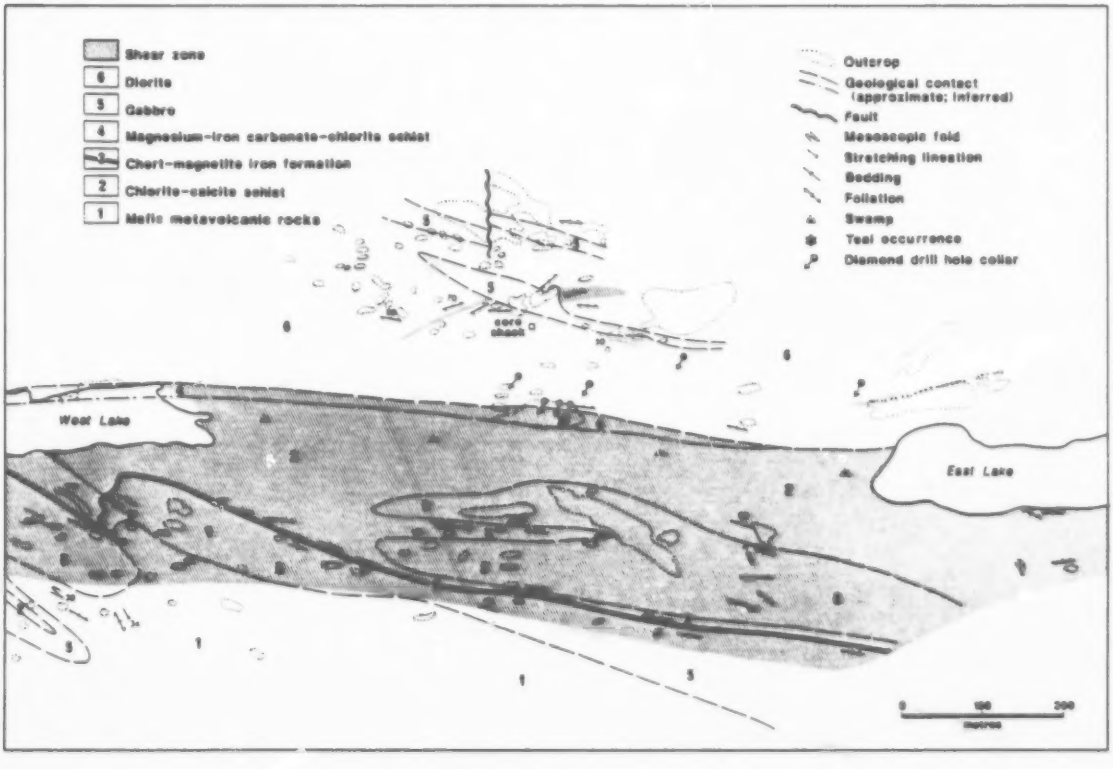

Figure 16. Geology of the Teal Property area.

Chert-magnetite iron formation: A chert-magnetite iron formation unit 1 m to 3 m thick occurs near the southeastern shore of West Lake (Figure 16). The extent of this unit has been interpreted from aeromagnetic data (Assessment Files Research Office, Ontario Geological Survey, Toronto). The iron formation is in tectonic contact with the chlorite-calcite schist unit and gabbro, and locally may occur as a tectonic enclave within gabbro. Chlorite schist units up to 10 cm thick are commonly interbedded with centimetre scale laminations of chert and magnetite.

As observed in thin section, the chert is recrystallized to ribbons of fine grained quartz with fibrous, chlorite-rich laminae. The laminae occur around pyrrhotite porphyroblasts, which are interpreted to be pseudomorphs after magnetite (Plate 8b).

Gabbro: Gabbroic bodies intrude quartz diorite to the north of the gold occurrence, and the chlorite-calcite schist and mafic volcanics to the south (Figure 16). In the latter occurrence, the intrusion varies from coarse grained, equigranular gabbro to chlorite schist. The massive gabbro consists of 40% actinolite, 30% chlorite, 20% epidote, 5% calcite and less than 5% quartz. Actinolite occurs in a blocky habit, interpreted to be pseudomorphs after primary pyroxene, and the crystals are typically brecciated and show variable replacement by chlorite. Epidote is finely crystalline and occurs as laths, interpreted to be pseudomorphs after plagioclase. Quartz, which occurs in the groundmass, associated with the saussuritized feldspar, is fine grained, and shows undulose extinction. Calcite occurs as twinned grains filling microfractures, and as a minor component in the groundmass.

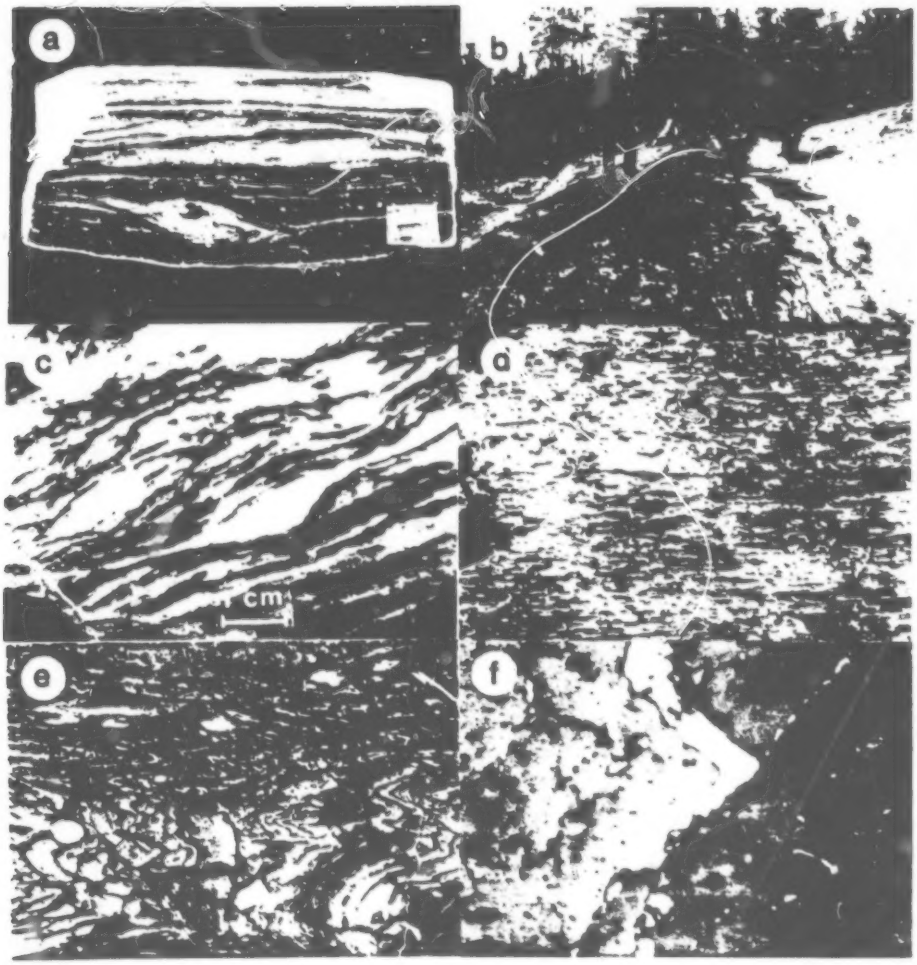

Plate 8. Lithologies and mineralization near the Teal Occurrence.

(a) Slabbed hand sample showing pyrrhotite porphyroblasts (pseudomorphs after magnetite) in magnetite bands from BIF near West Lake. (b) Outcrop showing Mg-Fe carbonate-quartz-chlorite schist (host rock from Teal Occurrence) in contact with diorite. (c) Slabbed hand sample of typical schist (see b) showing boudinaged quartz-carbonate veinlets. (d) Outcrop of chlorite-carbonate schist from south of the Teal Occurrence, showing an elongate, felsic (quartz-rich) fragment. (e) Outcrop, near West Lake, of tight, east-plunging intrafolial folds developed in BIF enclosed in schistose gabbro. (f) Photomicrograph of native gold (pale mineral at centre) in quartz-filled fracture cross-cutting massive arsenopyrite.

Massive, medium grained, gabbro dikes intrude the quartz diorite unit north of the gold occurrence (Figure 16). These dikes are amphibole-rich, cut the regional foliation, and consist of 60% fibrous, blocky actinolite pseudomorphs after pyroxene and 3-5% brown, strongly pleochroic, euhedral hornblende which is rimmed by skeletal magnetite and hematite; this is presumed to be relict magmatic basaltic hornblende. Other minerals include 20% fine grained epidote, pseudomorphic after feldspar, 15% chlorite, occurring as fibrous aggregates locally replacing amphibole, and 3% anhedral magnetite.

Quartz diorite: In the northern portion of the property, a fine to medium crystalline, massive quartz diorite unit is bordered to the south by a unit of Mg-Fe carbonate-chlorite schist (Figure 16). The quartz diorite consists of 30% euhedral to subhedral plagioclase (An_{42}), 20% interstitial, fine to medium crystalline quartz, 25% hornblende, 15% chlorite and 10% intermixed, finely crystalline sericite, epidote and calcite. Plagioclase is partially to totally replaced by the sericite-epidote-calcite assemblage and hornblende is commonly intergrown with, rimmed by, or totally replaced by chlorite. Quartz invariably shows some strain, as undulose extinction, and commonly contains acicular rutile inclusions.

Quartz-Fe-Mg carbonate-chlorite schist: A northeast-trending, northwest dipping (55° to 70°), semi-continuous unit of quartz-Mg-Fe carbonate-chlorite schist is intermittently exposed between East and West lakes (Figure 16). This unit is less than 20 m thick and is characterized by its fissile nature and strong rusty brown weathering (Plate 8c). Mineralogically, the schist consists predominantly of

carbonates, quartz and chlorite, with subordinate amounts of muscovite, talc and epidote (Plate 8d). Semi-quantitative, X-ray diffraction analyses suggest that the carbonate minerals consist of more than 50% dolomite, 40% magnesite (which has a 10% siderite component), and 10% calcite. Lozenge-shaped zones, or lithons (10 m by 3 m in size), of altered diorite locally occur within the schist adjacent to the diorite contact.

Structure

Common to most of the outcrops on the property are a steeply to moderately (55° to 90°) northwest-dipping, tectonic foliation, and a moderately (50° to 70°) northeast-plunging mineral lineation. The foliation and lineation development is most intense within a 200 m to 300 m wide zone, located immediately south of the quartz diorite, which is interpreted as a shear zone (Figure 16). This shear zone is coincident with the North Caribou River Fault (Map P. 2834; Bartlett *et al*. 1984). The nature of the shear zone is illustrated by the changes which occur in the metagabbro which crops out south of the fault between East and West Lakes. Chlorite schist zones, which cut the metagabbro and are parallel to the trace of the main fault, increase in width and abundance northward towards the main schist zone which marks the fault/shear zone.

Medium-scale, isoclinal and asymmetrical, "S" and "Z" shaped folds are present within the chert-magnetite iron formation exposed near West Lake (Plate 8e). The fold hinges plunge moderately (30° to 65°) east-

southeast, oblique to the trend of foliation and mineral lineations observed in the same outcrops.

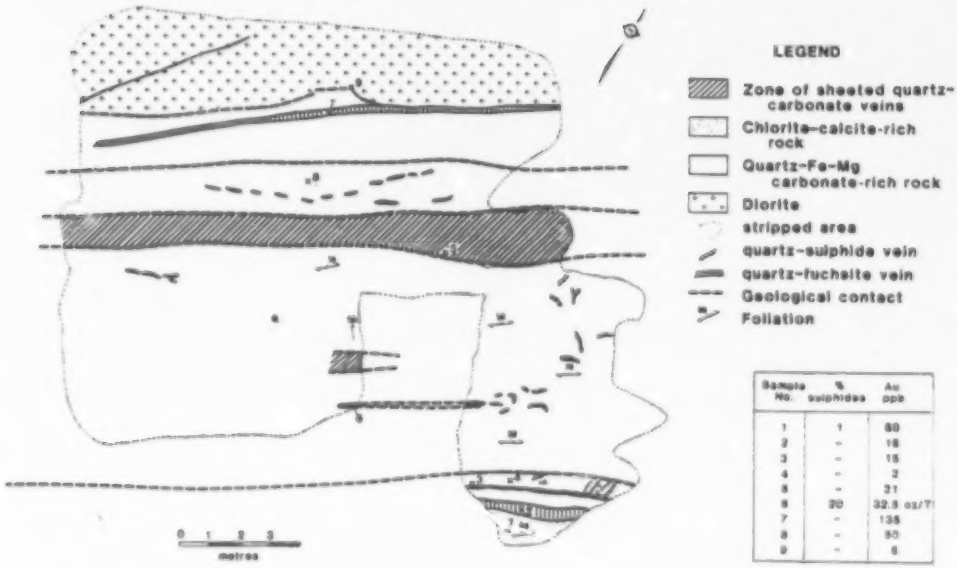

Figure 17. Detailed geology of the Teal Occurrence area.

Mineralization

The Teal Showing is located within the shear zone and is hosted by the quartz-Mg-Fe carbonate-chlorite schist unit. It consists of narrow (1 to 10 cm), discontinuous, foliation subparallel, quartz-carbonate veins which may contain local sulphide-rich pods (75% sulphides). The veins are typically boudinaged (Plate 8d). Sulphide pods, which are less than 0.5 cm in size (Figure 17), consist dominantly of arsenopyrite, tetrahedrite and chalcopyrite, with lesser pyrite, pyrrhotite and native gold (Plate 8f). Trace element geochemistry has

also identified anomalous Cr, Ni and Zn in the sulphide pods; no mineral species bearing these elements was observed, although sphalerite is suspected.

Grab samples of the sulphide-rich material have assayed up to 11,998 g/t (35 oz/ton) Au, 2% Ag, 8% Cu and 0.5% Zn, but samples from the adjacent schist and from quartz-Fe carbonate-fuchsite-chlorite veins barren of sulphides have yielded low gold values (Figure 17). Diamond drilling programs on the property did not intersect significant mineralization down-dip or along strike from the main surface showing.

Sulphide-rich quartz veins have not been observed outside the Mg-Fe carbonate-chlorite schist unit and gold values less than 200 ppb have been obtained from grab samples of the chert-magnetite iron formation.

VAN HORNE GOLD EXPLORATION INCORPORATED (NEAWAGANK LAKE PROPERTY)

Location, Ownership and Development

The Neawagank Lake Property is situated immediately north of Neawagank Lake (Figure 1; back pocket). The property consists of 37 claims which were initially staked during 1981 and 1982 by 493217 Ontario Ltd., which carried out geological mapping, prospecting, trenching and geophysical surveys (Assessment Files Research Office, Ontario Geological Survey, Toronto). The property was acquired by Texas-U.S. Oil and Gas Incorporated, which completed a diamond drilling program (6 holes; 598 m) in 1984 and 1986. The current owner, Van Horne Gold Exploration Incorporated, resampled the trenches and carried out geological mapping in 1986.

Geology

Description of Lithologies

Mafic volcanics: On the basis of limited outcrop and interpretation of geological data, the southeastern portion of the Neawagank Lake Property is thought to be underlain by an approximately 1.2 km thick sequence of northeast-trending, fine to medium grained, pillowed and massive mafic flows (Map 4; back pocket). These rocks are typically composed of variable amounts of hornblende, carbonate and sulphides (pyrite and pyrrhotite). Outcrops of pillow lava, exposed 500

m to the south of the property boundary, indicate that the sequence may face south.

Felsic to intermediate volcanics: Two outcrops of felsic to intermediate volcanics which occur on the Neawagank Lake Property are shown as two lensoid units of intermediate to felsic volcanics on Map 4 (back pocket). The unit exposed near Wesley Lake is interpreted as a felsic breccia, which is characterized by quartz-rich fragments within a very fine grained matrix of quartz + plagioclase + muscovite + calcite + biotite. The second unit, exposed 200 m west of Newagank Lake, is interpreted to be a 3 m thick flow and occurs intercalated with the pillowed mafic volcanics. This rock is characteristically fine grained and consists of quartz + plagioclase + microcline + chlorite + muscovite.

Iron formation: Iron formation is not exposed on the property, but a northeast-trending aeromagnetic anomaly within the mafic sequence is interpreted to represent a unit of iron formation. The strike length of the anomaly on the property is 1.2 km.

Mafic intrusive rocks: Gabbroic intrusive rocks are the dominant and best exposed lithologies on the property. These are interpreted to occur as a northeast tapering wedge (Map 4; back pocket), which is thickest (1950 m) in the west portion of the property where outcrop is most abundant.

The predominant rock type in this unit is homogeneous gabbro. In the eastern portion of the property, the gabbro grades into quartz gabbro. North of Wesley Lake, anorthositic patches measuring 1.5 by 0.5 m in size on average occur within outcrops of homogeneous gabbro. In

the same area, anorthositic gabbro and leucogabbro are present as isolated outcrops.

Typically the gabbros are massive, medium to coarse grained, and consist of variable amounts of hornblende + plagioclase + magnetite + quartz + biotite + chlorite + calcite. Quartz-rich varieties characteristically contain 5 to 10% blue-grey quartz.

Structural Geology

A northeast- to east-trending, steeply (85°) to vertically dipping foliation occurs in most of the outcrops on the property. The foliation is locally intensely developed within narrow (less than 2 m wide), discontinuous (less than 61 m long) shear zones which cut the gabbro to the north and east of Wesley Lake. The shear zones are parallel to the strike and dip of the foliation and locally host narrow quartz-carbonate-sulphide veins and massive to disseminated arsenopyrite.

Mineralization

On the Neawagank Lake Property, several gold occurrences occur within the narrow (0.5 m to 1.8 m wide), northeast- to east-trending quartz-sulphide-rich shear zones which cut the gabbro (Map 4; back pocket). The most significant gold values are associated with pods of massive to disseminated (1 to 2%) arsenopyrite, and numerous, foliation subparallel, quartz-pyrite-pyrrhotite veins (15 cm to 1.0 m wide) and veinlets which occur intermittently along the shear zones. The five most significant gold occurrences, known as the N-1, N-2, N-3, N-4 and N-5 Showings (Assessment Files Research Office, Ontario Geological

Survey, Toronto), are located in the east-central portion of the property and have returned gold values as high as 6250 ppb from samples taken by the authors. Most of the significant gold values obtained from this sampling are also coincident with high arsenic (up to 30% arsenopyrite) and antimony (up to 1180 ppm) values.

The diamond drilling program completed at the eastern portion of the property, in the vicinity of the N-1 to N-5 Showings (Map 4; back pocket), intersected multiple gold-mineralized zones, which are similar in character to, but cannot be correlated with, the surface showings.

VAN HORNE GOLD EXPLORATION INCORPORATED (OPAPIMISKAN LAKE PROPERTY)

Location, Ownership and Development

Van Horne Gold Exploration Incorporated owns 74 claims north of Opapimiskan Lake (Figure 1; back pocket and Figure 2). The general area was first staked in 1961 by Canadian Nickel Company Limited, which carried out airborne and ground magnetic and electromagnetic surveys in that year. In 1962 and 1963, a diamond drilling program was carried out (13 holes) by the same company; seven of these holes were collared on the present Opapimiskan Lake property. The claims were allowed to lapse and in 1981, 493217 Ontario Limited staked 46 claims to cover the northern extension of the iron formation which hosts the Musselwhite Deposit at Opapimiskan Lake. In 1981 and 1982, geological mapping, ground magnetic and VLF-EM surveys were carried out. In 1974, Koala Resources optioned the property from 493217 Ontario Limited and completed a detailed ground magnetic survey. The property was acquired by Van Horne Gold Exploration Incorporated in 1985, which carried out diamond drilling programs in 1985 and 1986 (12 holes, 1500 m and 30 holes, 3,187 m, respectively) and staked 28 additional claims.

General Geology

Geological mapping by 493217 Ontario Limited in 1982 and diamond drilling by Van Horne Gold Exploration Incorporated in 1985 (Assessment Files Research Office, Ontario Geological Survey, Toronto) indicate that the property is underlain by a lithological sequence which is very

similar to that described by Hall and Rigg (1986) at the West Anticline Zone of the Musselwhite Property. This sequence is interpreted to be folded into a megascopic, northwest-plunging (25°), Z-shaped fold based on geophysical surveys and diamond drilling (Assessment Files Research Office, Ontario Geological Survey, Toronto). The west limb of this fold (Figure 2) can be traced southeastward to Snoppy Lake.

Mineralization

In 1982, 493217 Ontario Limited obtained anomalous gold values from sulphide-bearing iron formation outcrops located approximately 200 m north of Opapimiskan Lake. The best gold values obtained from chip sampling by these workers are 2744, 1061 and 1001 ppb over widths of 3.5 m, 1.5 m and 2.0 m, respectively. In addition, a sulphide-bearing gossan zone located 2.5 km northwest from the iron formation outcrops was sampled and a 1852 ppb gold value over a 0.75 m width was obtained (Assessment Files Research Office, Ontario Geological Survey, Toronto).

Diamond drilling by Van Horne Gold Exploration Incorporated was located in the vicinity of the surface showings hosted in banded iron formation. The results of the drilling (Assessment Files Research Office, Ontario Geological Survey, Toronto) indicate that gold mineralization occurs in sulphide-bearing zones, up to 3.0 m wide, hosted within chert-grunerite-magnetite iron formation and garnet-biotite schist at or near the crest of the antiform (described below). This mineralization and structural style are similar to those described at the West Anticline Zone of the Musselwhite Property by Hall and Rigg (1986). The most significant gold intersections obtained in the

drilling program include: 56 ppm over 0.85 m, 34 ppm over 1.34 m, 15 ppm over 2.8 m and 6.9 ppm over 1.5 m (Assessment Files Research Office, Ontario Geological Survey, Toronto). The continuity and geometry of the mineralized zones are not known.

PLATINUM AND PALLADIUM IN MAFIC-ULTRAMAFIC METAPLUTONIC ROCKS

Anomalous levels of platinum and palladium, up to 31 ppb and 74 ppb respectively, were discovered during this study in previously undocumented sulphide mineralization at two localities within the Karl Lake Plutonic Complex (Figure 1 and Table 3).

Table 3. Pt, Pd, Au, Cu, Ni, Cr and Zn analyses for sulphide mineralization associated with the Karl Lake Mafic-Ultramafic Plutonic Complex.

	Pt (ppb)	Pd (ppb)	Au (ppb)	Cu (ppm)	Ni (ppm)	Cr (ppm)	Zn (ppm)
Karl Lake Chalcopyrite-Pyrrhotite Locality							
A26-12 I	5	55	35	910	57	136	92
12 II	3	26	30	875	59	85	106
12 III	8	74	70	1520	50	107	108
12 IV	5	35	25	790	53	77	106
12 V	31	22	100	1420	57	58	110
12 VI	6	17	13	495	39	51	107
Pipestone River Chalcopyrite-Pyrite-Pyrrhotite Locality							
Z25-4 I	<1	<1	3	<5	7	277	<5
4 II	3	28	17	765	17	94	27
4 III	5	12	40	1420	44	146	32
4 IV	3	14	70	3880	11	84	18

On the southern shoreline of Karl Lake (UTM 692200/582870), fine to coarse grained chalcopyrite is disseminated uniformly throughout massive, medium to coarse grained, biotite porphyroblastic amphibolite. This 3 by 15 m outcrop is exposed at low lake levels only. In total, chalcopyrite is probably less than 0.5% of the rock, but locally it is

Subordinate, anhedral pyrrhotite occurs mainly in the zones of higher chalcopyrite abundance.

In the early 1960's, International Nickel Company of Canada Limited tested nearby electromagnetic conductors with two diamond drill holes (Assessment Files Research Office, Ontario Geological Survey, Toronto). No assays of platinum group metals were reported from this mineralization, and it may be prudent to reconsider these zones in view of the anomalous levels of Pt and Pd demonstrated by the present survey.

A second occurrence of sulphide mineralization is exposed on the Pipestone River, downstream from Karl Lake (UTM 68990/58294). A gossan (about 9 m^2), exposed only at low water level, has developed over narrow, plagioclase-rich veins which contain 5 to 10% chalcopyrite, pyrite and pyrrhotite. These sulphides occur as disseminated grains and stringers which tend to be concentrated within the neck zones of the boudinaged plagioclase-rich veins. These veins tend to parallel the foliation of the biotite amphibolite host.

METALLOGENETIC SUMMARY

The properties described in this report can be subdivided geographically into three areas: the Agutua Arm area, the North Rim, and the Opapimiskan - Neawagank - Libert Lakes (Opapimiskan) area. Most of the contrasts in geological features of these three areas, such as the host rocks for gold mineralization, mineralization types and alteration types, can be explained in terms of the metamorphic grade of the area. Other differences, such as the structural styles and the intrusive rock types, cannot be attributed to metamorphic grade. In general, the properties located in the Agutua Arm area occur within rocks metamorphosed to greenschist grade, while those in the Opapimiskan Lake area and along the North Rim occur within rocks of amphibolite grade. The aim of the following summary, which compares and contrasts the geology of the three areas with reference to gold mineralization and the metamorphic grade, is to determine which area shows the highest potential for gold mineralization, based on the existing data base.

Host Rocks for Mineralization

In the Agutua Arm region, the host rocks for gold mineralization include mafic volcanics and quartz-dolomite-chlorite schist. The schist is interpreted to be ultramafic in origin. In contrast, the mineralization within the amphibolite grade rocks at both the Opapimiskan and North Rim areas is hosted predominantly by iron formation and Fe-rich metasedimentary schist units, with lesser amounts in mafic volcanic rocks and gabbro (Table 4).

Table 4. Host lithologies for gold mineralization in the North Caribou Lake Greenstone Belt.

GREENSCHIST GRADE	AMPHIBOLITE GRADE	
Agutua Arm	Opapimiskan Lake	North Rim
mafic volcanics	iron formation	
quartz + Fe dolomite schist	metasedimentary schist	
	mafic volcanics	

In most cases, the lithologies hosting gold mineralization can be placed within the regional stratigraphy established in this study and by Hall and Rigg (1986). An exception to this is the Teal Occurrence in the North Caribou River Fault. In the Agutua Arm area (Figure 18), the gold occurrences are located within the oldest mafic volcanic rocks (the Agutua Arm Volcanics), and within ultramafic rocks and quartz porphyritic intrusions of a younger sequence (Keeyask Lake Volcanics). Gold occurrences in the Agutua Arm area have not been discovered in the mafic volcanic rocks of the Keeyask Lake Volcanics, in iron formation, or in the clastic metasediments. Although these two volcanic-sedimentary sequences are interpreted to differ in age, there is a strong possibility that they represent sequences repeated by faulting.

In the Opapimiskan Lake area, gold occurs within a specific ironstone unit (Figure 18), referred to as the Middle Ironstone by Hall

and Rigg (1986), which comprises chert-magnetite-grunerite-garnet (almandine)-hornblende iron formation (the main host for gold mineralization) and cherty iron formation. In addition, gold mineralization can be found almost anywhere in the Hangingwall Metasediments, which include quartz-biotite-garnet schists and laminated chert-magnetite-garnet-biotite schist. The Southern Ironstone Unit, which consists of chert-grunerite iron formation, and the ultramafic unit, which consists of a tremolite schist, are also mineralized in the vicinity of the West Anticline Zone of the Musselwhite Property.

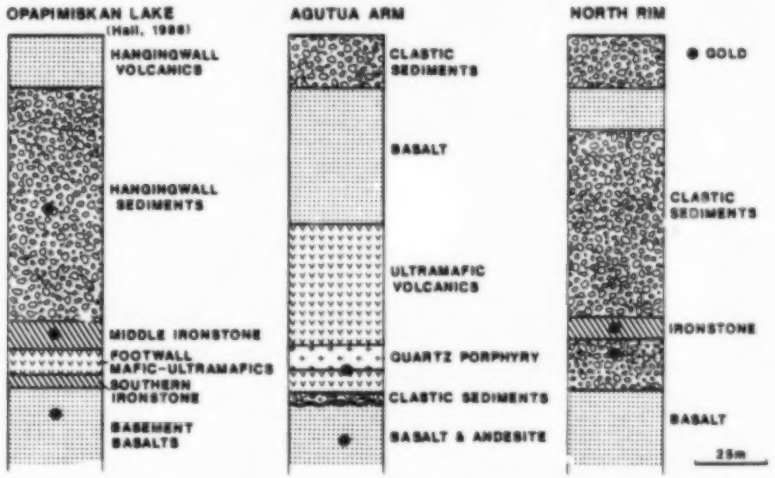

Figure 18. Stratigraphic sections of the Agutua Arm, Opapimiskan Lake and North Rim areas.

The lithologies and stratigraphy at Opapimiskan Lake cannot be directly correlated with the lithological sequence along the North Rim. However, gold does occur in similar lithologies along the North Rim (Figure 18), including intercalated chert-magnetite-grunerite iron

formation and quartz-biotite-sericite-garnet-staurolite-andalusite-chlorite schist. Gold mineralization also occurs in the quartz-biotite-garnet schists which occur on the north flank of the iron formation, but gold has not been discovered in the older mafic volcanic rocks to the north (North Rim Volcanics) or in the younger clastic metasediments (Eyapamikama Lake Metasediments) to the south.

Table 5. Styles of gold mineralization in the North Caribou Lake Greenstone Belt.

GREENSCHIST GRADE	AMPHIBOLITE GRADE	
Agutua Arm	Opapimiskan Lake	North Rim
QUARTZ VEINS	DISSEMINATED IN HOST ROCK	
(aspy, tetra, cpy, py)	(po, aspy)	(po, aspy, gn, sp, cpy)
disseminated in host rock	quartz veins	
(aspy, py)	(po, aspy, gn, sp, sch, cpy, py, native Au)	(aspy, po)

Mineralization Types

There is a distinct difference in mineralization types in different host rock lithologies and in areas of different metamorphic grade (Table 5). In the greenschist grade rocks of the Agutua Arm area, gold occurs mainly with quartz-sulphide (arsenopyrite, pyrite,

chalcopyrite and tetrahedrite) veins, with only a minor amount in the adjacent wall rock. This is in contrast with the Opapimiskan and North Rim areas, where gold occurs with sulphides (pyrrhotite, arsenopyrite) which dominantly occur disseminated in the ironstone host rock, and only to a minor extent within quartz veins. Quartz veins are, however, abundant within the mafic host rocks at the Libert Lake and Neawagank Lake Properties, similar to occurrences in the Agutua Arm area. A gold occurrence associated with disseminated base metal sulphides, high Ag values, and low As values within biotite-garnet schist is unique to the Arseno Lake region along the North Rim.

Alteration Types

Although, in general, alteration is difficult to recognize on an outcrop scale, there is a distinct difference in the alteration related to mineralization in the greenschist and amphibolite grade rocks (Table 6). Where alteration can be recognized in the Agutua Arm region, it occurs as narrow, quartz + Fe carbonate + chlorite-rich halos around quartz-sulphide veins (*e.g.* at the Pyrotex Occurrence). In contrast, at the West Anticline Zone of the Musselwhite Property at Opapimiskan Lake, Hall and Rigg (1986) have shown that the mineralized zones are coincident with disseminated pyrrhotite, with the partial to complete gruneritization of magnetite laminae (resulting in a destruction of primary bedding), and with an increase in garnet (almandine) content. The pyrrhotite association is considered most important, despite the fact that pyrrhotite may be present in amounts as low as 1%. In addition, there may be an increase in amounts of biotite or albite (2 to

3%) and locally of cobalt and nickel arsenides (Hall and Rigg 1986) associated with gold mineralization.

Table 6. Types of hydrothermal alteration related to gold mineralization in the North Caribou Lake Greenstone Belt.

GREENSCHIST GRADE	AMPHIBOLITE GRADE	
Agutua Arm	Opapimiskan Lake	North Rim
quartz + chlorite + Fe dolomite	gruneritization of magnetite	?
	high concentration of garnet	
sulphidization	sulphidization	sulphidization

Within metasedimentary rocks other than the Middle Ironstone Unit in the Opapimiskan Lake and North Rim regions, grunerite and garnet are relatively abundant and widespread and it is therefore difficult to use them as indicators of alteration related to mineralization.

Structural Styles

The anomalous concentration of gold in ironstone at Opapimiskan Lake is spatially coincident with a high level of regional scale, complex folding, which is well illustrated in the West Anticline Zone and the Snoppy Lake Area (Figure 2). Both of these occurrences are located at or near the crests of complex folds. The mineralization at the West Anticline Zone closely mimics the geometry of the folded Middle Ironstone Unit and is relatively more extensive along the northwest

Ironstone Unit and is relatively more extensive along the northwest plunge than it is laterally. In spite of the stratabound nature of the gold mineralization, the concentration of sulphides and the vein-style mineralization are parallel to the axial planar foliation and are therefore vertically dipping and cut across bedding and the lithological units.

Regional scale folding of the metasediments at the western end of Eyapamikama Lake is similar in style to that defined by geophysics and drilling in the Opapimiskan Lake area, but ironstones and gold occurrences have not yet been discovered at Eyapamikama Lake. Geophysics has not been helpful in delineating the regional geometry of the folding at Eyapamikama Lake because of the low magnetic susceptibility of the rock and the presence of lithologically homogeneous units.

In contrast to Opapimiskan Lake, all of the ironstone in the northern and northwestern portions of the greenstone belt is interpreted by geophysics to occur in areas showing a lack of regional scale complex folding. Along the North Rim, small scale folding of the iron formation is present on a local scale, and these areas show a close spatial relationship with the known gold occurrences, especially in the McGruer and Castor-Pollux Lakes region. For example, at McGruer Lake, the scattered gold occurrences are located adjacent to a truncated fold which has been defined by mapping and ground geophysics. The fold styles along the North Rim are slightly different from those at Opapimiskan and western Eyapamikama Lakes in that they are tighter (sometimes isoclinal), and plunge more steeply, averaging about 45° to

the east or west. This type of tight folding, with truncated limbs and local refolding, is restricted to the 200 to 400 m wide shear zone coincident with the volcanic-sedimentary contact. This zone is interpreted as a shear zone, but there is little kinematic evidence for a fault (*i.e.* a lack of well developed stretching linear fabrics), and there is a lack of recognizable alteration. In addition, well developed quartz vein systems have not been discovered along the shear zone and those that are present are narrow, discontinuous, extensional features, barren of sulphides and gold values outside the ironstones.

In the Agutua Arm region, the scattered gold occurrences are spatially associated with zones of structural complexity characterized by well developed planar and linear fabrics, medium scale folding, and local truncation of lithologic units. The structurally complex zones include the North Caribou River Fault and a zone which can be traced intermittently northward from Center Lake to Keeyask Lake. In contrast to Opapimiskan and Eyapamikama Lakes, the fold styles in the Agutua Arm region are relatively open and steeply plunging (60° to 90°).

Intrusive Rocks

There are no significant intrusions in the belt which can be directly related to the gold occurrences. However, at Opapimiskan Lake, a series of albite pegmatite dykes which contain gold values and anomalous concentrations of rare metals are present. The origin and significance of these dikes have been discussed by Breaks *et al.* (1987).

Albite pegmatite dikes or mica-rich granites have not been observed in the Agutua Arm or North Rim areas. Quartz-sericite schist

units are, however, present in the McGruer Lake and Centre-Keeyask Lakes regions, and are interpreted to be of intrusive origin. These units show a close spatial relationship to the gold occurrences at these locations and locally contain quartz-tourmaline-sulphide veins, which in one instance (Center Lake) contain significant gold values. The schists themselves, however, do not contain significant gold values.

CONCLUSIONS

1) Gold mineralization occurs predominantly within Fe-rich lithologies located in specific stratigraphic positions.

2) There is no preference for mineralization in rocks of a particular metamorphic grade, but the most significant occurrences discovered to date are within amphibolite grade rocks.

3) Gold mineralization shows a spatial relationship with areas that are both structurally and lithologically complex.

4) The most reliable indicator minerals for gold mineralization are sulphides (pyrrhotite, arsenopyrite, pyrite), which may be present in amounts as low as 1%. Significant amounts of quartz veining may be absent from gold mineralized zones.

5) Visible wallrock alteration related to mineralization may be subtle, especially in the amphibolite grade rocks where both altered and unaltered Fe-rich host rocks contain assemblages of garnet + grunerite, and where both may display complete destruction of magnetite.

MINERAL POTENTIAL

GOLD

Gold mineralization occurs in all five regional supracrustal units delineated within the North Caribou Lake Belt (Breaks *et al.* 1984, 1985). As discussed above, the occurrences can be separated into two categories: those in greenschist grade rocks and those in amphibolite grade rocks. In addition, the occurrences in each category can be compared and contrasted in terms of their geological characteristics.

Amphibolite Grade Rocks

The most significant known gold occurrences in amphibolite grade rocks are hosted by ironstone units located in the Opapimiskan Lake region (West Anticline and Snoppy Lake Zones). These occurrences display geological characteristics that can be used as criteria for gold exploration on both a regional and local scale.

On a regional scale, the most readily recognizable characteristic in the Opapimiskan Lake area is the complex structural pattern, involving polyphase folding of the ironstone units. This regional structural pattern is easily detectable using airborne magnetic maps, and the recognition of such patterns is considered to be the best guideline for reconnaissance scale exploration. The interpreted iron formation unit in the Neawagank Lake region shows complex magnetic patterns similar to Opapimiskan Lake and is considered to have relatively high potential for gold mineralization.

The preferred host rocks for gold mineralization at Opapimiskan Lake and within amphibolite grade rocks elsewhere in the greenstone belt include chert-grunerite iron formation and garnet-biotite schist.

On a detailed scale, the most important but most difficult characteristics to recognize at the West Anticline Zone are the subtle alteration, and the low percentage of visible sulphides and quartz veining within the mineralized zones. When exploring for gold elsewhere in the belt, iron formation and garnet-biotite schist units should, therefore, be carefully prospected and sampled for gold analysis in all cases, to compensate for the subtlety of alteration and mineralization.

In areas of complexly folded iron formation, detailed ground magnetic and electromagnetic surveys and detailed mapping should be undertaken to delineate drill targets. Care must be taken to determine the plunge of lithologies in the areas proposed for drilling since the mineralization at the West Anticline Zone has been shown by Hall and Rigg (1986) to closely parallel the plunge of regional folds. Drill holes should be oriented to intersect the regional structural trends at the highest angle possible and should not be oriented parallel with them.

Greenschist Grade Rocks

Within the greenschist grade rocks, known gold occurrences show consistent characteristics which can be used as criteria for exploration. On a regional scale, all of these occurrences are within shear zones, which vary in width from metres to hundreds of metres, and are hosted by, or show a close spatial association with, quartz-

carbonate-rich rock. The shear zones are best delineated by careful mapping and in some instances can be identified on airborne magnetic or electromagnetic maps, where they occur as linear anomalies.

On a detailed scale, most of the occurrences are characterized by the presence of quartz-sulphide veins, but sparsely sulphide-mineralized wall rock containing gold values is also present (*i.e.* Centre Lake). A preferred host for quartz-sulphide veining, which is relatively easily detectable using geophysical techniques, is the relatively brittle iron formation units which are intercalated with the volcanic sequence, such as observed immediately south of the portage trail linking Eyapamikama and Pakiagama Lakes. Altered and mineralized shear zones in mafic volcanic rocks may also show weak geophysical responses and can also be considered as exploration targets.

Platinum

Further exploration considerations should be extended to platinum group elements (PGEs) within the map area. The previously undocumented, locally layered, Karl Lake ultramafic-mafic anorthositic complex contains anomalous platinum and palladium (Table 3). Ultramafic intrusive rocks are also evident at the western end of Forester Lake, and along with scattered masses of metagabbro between the Pipestone River and Neawagank Lake, and should receive some examination for PGE mineralization.

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